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SCREW STEAMSHIP AND TOW BARGE EFFICIENCY ON THE NORTHWESTERN LAKES OF AMERICA.

By JOSEPH R. OLDHAM, N. A., Cleveland, O., 1891.

WITH DISCUSSION.

The subject of the "American Whaleback Steamers" and towage on the northwestern lakes is one of great interest at the present time. About twenty-five years ago there were built in London several vessels having circular midship sections, and extremities somewhat resembling these "whalebacks," but it would seem that their demise followed rapidly upon their inception. These vessels were called "cigar ships." Again about midway between that period and the present date another cylindrical floating iron vessel was constructed to carry the Egyptian Obelisk, or Cleopatra's Needle, to London. This vessel, after an adventurous voyage over the Bay of Biscay, appears to have accomplished her life's work in one single effort of usefulness. But not to such as these may we liken Captain McDougall's invention, for within two years of regular building not fewer than 70 000 tons of shipping is represented by these ubiquitous barges.

It was said some time since that the northwestern lakes would

soon be flooded with the McDougall barges, and now it really seems as if this prophecy would very soon be consummated, for in his last trip up these lakes the writer passed no fewer than three tows of these vessels, besides the *Colgate Hoyt*, and the tow with which he came quickly and pleasantly down the lakes. About this tow something more will be said later on. In the meantime it may be stated that this flooding of the lakes with whalebacks is not looked on complacently by either our ship-builders or ship-owners. As the question is often asked, the author desires to state his opinion that, given sufficient free board, strength and power, the North Atlantic trade may be safely carried on in such vessels.

Good speed should be a *sine qua non* when equipping a properly loaded steamer for running before an Atlantic gale. Form taken by itself is but a poor condition of safety, for a good model will not behave well in a seaway if overloaded; and an inferior model may do fairly well if she retains sufficient surplus buoyancy. This remark should be qualified by saying that ordinary cargo steamers only are now referred to.

There is nothing more suprising about these whaleback steamers than their extraordinary speed, considering the low power and small consumption of fuel required, unless it is the ease with which the whaleback barges tow, when we take into account their large capacity and enormous dead-weight ability. For example, the steamship *Joseph L. Colby*, with only 850 indicated horse-power, can tow not fewer than three of these vessels nearly 8 miles per hour. This would not be bad work if such a boat were light, but when we learn that this can be accomplished with 400 000 bushels or nearly 9 000 tons of wheat on board, the efficiency may surely be called phenomenal; for though it is generally assumed that the thrust from a screw propeller is greater than the tow-rope pull, this is not always the case. It is frequently stated that the thrust of a propeller does not exceed 60 per cent. of the horse-power developed, but in the Admiralty experiments with the screw steamer *Rattler* the efficiency was as high as 80 per cent. Some particulars of this steamer and her trials may here be quoted. The indicated horse-power of her engines was 428. The thrust of the shaft, with a dynamometer which should measure the forward effort of the screw was about 8 000 pounds. If this be multiplied by 1 013, the speed of the vessel in feet per minute, and divided by 33 000, it gives 245 as the horse-power utilized; and assuming that the indicated horse-power was 428,

this is only a little over 57 per cent. of the indicated engine power. It is said that the efficiency in this instance fell on account of a strong head wind, though the thrust was then greater than when the efficiency percentage was 84.

Now, if we assume an equal state of efficiency in the screw steamer *Joseph L. Colby*, it will still be somewhat phenomenal to see her steam off with three of these loaded barges as she does. But let us take an example of these barges being towed by an ordinary lake steamer. A few weeks since it was the author's good fortune to make a trip from Lake Superior in the handsome wooden steamer *Sitka*, of the Wilson Line. The barges 105 and 109 were in tow, with a combined cargo of over 4 700 tons dead-weight on board. The *Sitka* carried in addition 1 900 tons, including her fuel; hence, the total dead-weight carried was 6 600 tons, and the gross displacement of all three vessels would not be less than 10 600 tons, or about the same as the ocean mail steamers *City of Rome* or *Servia*. A careful timing of the vessel proved beyond a shadow of doubt that the *Sitka* steamed with its tow fully $8\frac{1}{3}$ miles per hour on the average. But let us take some other means of comparison before we lay claim to this high efficiency. The registered dimensions of the *Sitka* are 272 x 40 x 19 feet, and her tonnage is of the gross register 1 741 tons. She has triple expansion engines, the diameters of cylinders being 20, 32 and 52 inches respectively, and common stroke of piston 40 inches. The boilers are of the Scotch type and are 132 inches in diameter by 12 feet in length, and they have four flues or furnaces, each 46 inches diameter, the working pressure being 150 pounds per square inch. The author was not able to ascertain the mean indicated horse-power exerted by the engines during the run measured, and cannot, therefore, say what was their minimum power, but can estimate her maximum power without inaccuracy. Lloyds give the following rule to be used for determining the nominal horse-power of triple expansion engines.

Rule: $\frac{1}{4}\left(\frac{D^2 \times \sqrt{S}}{100}\right) + \frac{H}{15}$ = nominal horse-power of triple expansion engines. Where D = the diameter of the low pressure cylinder in inches, S = stroke of piston in inches, H = the heating surface in square feet. If the result be multiplied by 5 it will show a power in excess of good practice for similar engines and boilers in ordinary working. By this rule, allowing the heating surface of the *Sitka's* boilers to be 3 000 square feet, the engine would be developing $927\frac{1}{2}$ horse-power. However, as

the author is not certain as to the exact effective heating surface, let us test this by a rule of our own, which is :

$$\frac{1}{5}\left(\frac{D^2 \times \sqrt{S}}{10}\right) \times (F^2 \times N \times 50) = \text{I. H. P.}$$

Where D and S are as before, $F =$ diameter of furnace in feet, $N =$ number of furnaces. By this formula the power would be 929.6 horse-power.

Permit the quotation of one more rule for approximating the horse-power of marine engines, and then we may not hesitate to give the limit of the power of these engines, or indeed any common marine screw engine in ordinary working without mechanically forced draft:

$$\text{I. H. P.} = \left(\frac{D^2 \sqrt[3]{S} + 3H}{100}\right) \sqrt[3]{P}.$$

Where $D =$ the diameter of the low pressure cylinder in inches, and if there is more than one low pressure cylinder, let $D =$ the sum of the squares of the diameters, S and H are as before, $P =$ the working boiler pressure in pounds per square inch above the atmosphere. By this rule these engines would indicate 969 horse-power, and the mean power by the three formulas would be 942. Let us be liberal, however, and assume that these engines were indicating as much as 950 horse-power. In connection with this it must be mentioned that the height of this steamer's stack would be nearly 60 feet ; and if we assume that every 10 feet in height supplies a draft equal to $\frac{1}{16}$ inch of water pressure, there would be about $\frac{3}{8}$ of an inch total pressure. The furnaces were large in diameter, there being wisely but two fires in each boiler. Parenthetically it may be remarked that the man who attempts to work three corrugated furnaces into a boiler not more than 12 feet in diameter, would become a better designer if he spent some time as a "shovel engineer." For, remember, that the outside of the corrugation limits the cleaning and water circulating space, whilst the diameter inside of such corrugations limits the diameter for fire bars as well as the opening for the passage of air; and if we allow, say, 10 inches depth of coal on top of such fire bars, we shall not then wonder at a low efficiency as regards consumption of fuel, if we bear in mind that the first duty of a furnace is to burn coal. It will be observed that the diameter of a furnace, or breadth of fire, only, enters into this calculation; for it does not appear that the length of furnace makes any appreciable difference in the power of a boiler; indeed, it is not an uncommon experience with marine

engineers to find the length of furnaces decreased with a corresponding increase in consumption of coal and power developed. Again, who has not known (at least with boilers that have been overtubed) of an increase of power following upon a reduction of heating surface? As to the power of the engine, we have taken the low pressure engine only in estimating this, for that only is necessary.

The indicated horse-power required to attain a certain speed may be ascertained from the following expression.

$$\text{I. H. P.} = \frac{\text{Speed}^3 \times \sqrt[3]{\text{displacement}^2}}{\text{co-efficient}}$$

This is based on the rule for the co-efficient of performance of a steamship in relation to the displacement, which says the cube of the speed in knots per hour, multiplied by the cube root of the square of the displacement in tons of the ship and divided by the indicated horse-power, equals the co-efficient of performance.

In the last column of the annexed table will be found constants applicable to the above formula for various types of screw steamers, having speeds from about 8 knots to nearly 25 knots per hour. Now the *Sitka's* average speed over the voyage under consideration was 8½ miles per hour; but thick weather and head winds lowered the average, for when such did not prevail the *Sitka* and tow could steam nearly 9¼ miles per hour, or slightly over 8 knots; hence, to equal this, our proposed vessel should be able to steam 8 knots per hour. Let us estimate what horse-power will be required to attain this speed approximately by another formula, based upon skin frictional or augmented surface resistance:

$$\text{I. H. P.} = \frac{S^3 \times L \times B + 2D \times 0.91}{20\,000}$$

where $S =$ the speed of the vessel in knots per hour, $L =$ the length and $B =$ the breath of the vessel, $D =$ the draft of water (mean). The divisor 20 000 expresses the number of square feet of augmented surface which can be driven at a velocity of 1 knot per hour by one indicated horse-power.

According to this rule the power required to transport 6 600 gross tons dead-weight of cargo on one bottom, at as great an average speed as that which the *Sitka* and her tow of two loaded whalebacks accomplished, would be 1 189 horse-power. By this it appears that an equal amount of freight can thus be carried in these three hulls with 20

per cent. less horse-power; and 20 per cent. saving in a steamer like the *Sitka* equals nearly 5 tons of coal every twenty-four hours.

Now, if we had to carry an equal dead-weight in one vessel on the same draft of water, a steamer 580 feet in length and 58 feet in breadth would be required. To drive this steamer at 8 knots per hour, engines of 1 189 horse-power would be necessary, which is certainly 20 per cent. more than the power of the *Sitka*, which propelled and towed 6 600 tons of dead-weight of cargo at an average speed of more than $8\frac{1}{2}$ miles per hour. To compare this vessel with the whalebacks as cargo-carrying machines, we must content ourselves in this instance with the gross displacement in each case, indicated horse-power, and speed of vessel; and this may best be done by the aid of the well-known formula above referred to, $\frac{V^3 \times D^{\frac{2}{3}}}{\text{I. H. P.}}$. This formula is based on the assumption that the resistance offered to the passage of a vessel through water is proportioned to the square of the speed; that the power required to propel the vessel varies as the cube of the speed, and as the cube root of the displacement squared. Although this may not be absolutely correct, it is quite near enough for our purpose at present, and as the resistance experienced by the fore end of a vessel varies exactly as the square of the speed, there is no reason for supposing that in properly formed vessels the after body should materially interfere with this method of comparison. By this formula we find that the efficiency of the equivalent steamer is represented by 213, and that the efficiency of performance of the whaleback tow is 247, which is much higher.

These vessels transported on this occasion one gross ton a distance of 100 miles for a consumption of 3.65 pounds of coal at $8\frac{1}{2}$ miles per hour; at a 10-knot speed, the best average the writer is acquainted with, equals one gross ton carried 100 miles for every 5 pounds of coal burnt. Of course this great discrepancy is largely attributable to the higher speed, the power to attain which varies as the cube of the velocity; but even when discounted in this way the result is still worth noting, for it represents in cost of coal one ton of freight carried 100 miles for less than one cent. Incidentally it raises the well-beaten problem of the most economical speed for a freight steamer. The author considers the average speed of modern lake steamers to be too high, as they are not required to run before an Atlantic gale.

The great length of tow-rope used on the lakes (frequently as long as

120 fathoms) has somewhat surprised the author, for he thought the nearer the power approached the resistance the greater the efficiency. We may assume, however, that these people with great experience know what is best, but there is probably another good reason for working with a long tow-rope. Rankine says, "that propeller is the best which drives astern the largest quantity of water at the least velocity;" or again, "the useful work of the propeller is proportional to the backward acceleration of the wake." Other authorities maintain that such water is left astern. We are assuming the vessel to be moving ahead, of course, not astern, but if it be true that the pressure on the after surface of the screw-blades is attained by the production of a partial vacuum on the fore side, it would seem that the water must be driven astern, perhaps not quite in the form of a regular twisted rope, as we often see illustrated, though that the screw-blades do give the water in contact with them some rotary motion appears from observation and deduction quite incontrovertible. There is no denying that the bow of a floating vessel, when in motion, does impart like motion to the film of water of more or less thickness which impinges on her skin. If the hull can thus impart motion to the water in the direction of its advance by the medium of skin friction, does it not follow that the screw-blades may also impart rotary motion to the film of water directly impinging on their surface as they revolve? Thus it would seem to be advisable to allow the "tow" to remain as far away from the water put into motion by the screw as possible, as well as not to interfere with the wave of replacement as it advances on to the stern of the propelling vessel.

With reference to the cost of towage the author may mention that the rule on these lakes is for the steamer to receive one-third of the freight due to the barge, but the McDougall barges are all being towed for one-fourth of their freight.

SELF-TRIMMERS.—The author calls these vessels self-trimmers, which name was given to certain steamers on the Tyne; and for this reason wing boards were fitted from the top sides, extending up to the deck and diagonally towards the center line of the vessels. Their province was to take away the vacant corner that is always left in an ordinary vessel, just at the junction of the top with the sides and deck; but the designer does not believe in vacant spaces at all, and so instead of hiding this corner, as it were, he takes the bold step of cutting the corner off altogether, thus enabling the cargo to fill the hold as full as

an egg, and that without padding of any kind. Thus these vessels may truly be called self-trimmers.

As regards collisions, if the object, when designing this bow, had been to produce the form of least destructive power, it could not have been accomplished better, for this is just the opposite of the ordinary upright stem or "ram" bow which so frequently does greater damage below than above the water line.

SEAWORTHINESS.—It may be remembered that when the official inquiry was held over the foundering of the then new mail steamer *London*, which went down with passengers and crew in the Bay of Biscay, it was proved that the foundering was caused by a spar breaking loose from its lashings on deck and knocking against the engine-room skylight till it gave way; the water found its way into the engine and boiler compartments, put out the fires, and the vessel became a helpless mass in the trough of the sea. From this it would seem that even the great spread of canvas carried by the *London* was practically useless to her in time of need. But what the author desires to emphasize is, the extreme danger there is in having light upper works, especially in "well" deck vessels.

At the twenty-seventh session of Naval Architects, Professor Elgar in his most interesting and instructive paper entitled "Notes upon Losses at Sea" described the foundering of a certain steamer, the principal dimensions of which were 260 feet 2 inches x 34 x 23 feet 9 inches and having 4 feet 9 inches freeboard when loaded with maize (which is a cargo of approximately the same density as wheat). A heavy sea was shipped, which smashed in deck-houses and sky-lights and found its way into the engine room and stokehold; other seas followed, tearing ventilators off and pouring into the engine-room and holds. She broached to and fell over to port, her lee rail being under water. The pumps were choked and the engines ceased to work, and the vessel was finally abandoned. The above description of foundering would no doubt be applicable to many a missing steamer if we knew the particulars leading up to their loss, hence it would seem that the most vulnerable parts of such steamers are their skylights, companions and deck-houses. The "whalebacks" are almost free of such openings to the holds, those that there are being raised far above the deck on the most substantial iron turrets or trunkways. It has been said that in all things, but proverbially in mechanics, simplicity is

supreme excellence. Now, surely, we have excellence here, for nothing could be more simple (consistent with strength and handiness) than these very vessels; there is absolutely nothing to be washed away. It may be said you have nothing to keep the sea off; well, if one has to walk over a rough road when it is raining in torrents and blowing a hurricane, one would much prefer to have a good macintosh coat on his back than to trust to the frail protection of a flimsy umbrella, and so a good strong deck, without weak incumbrances, is a much safer arrangement for a storm than all the usual paraphernalia of wood bulwarks and skylights as they are commonly fitted. Big seas will get on board, do what we may to prevent them, and it is the big seas that must be provided against, not the small ones. When such do come on board the less obstruction there is to their movement in the way of side houses, etc., the better. More than that, when the seas come up the sides of vessels like these they are water borne and do not sink the hull down ready for destruction by a bigger sea; while in the ordinary vessel, with bulwarks, etc., the seas that do the damage are those that are cut off from their fellows and make a lodgment on deck by filling the "wells," when, if they do not carry all before them, they sink the vessel down, ready for the reception of another wave that does the damage. Instead of theorizing let us take an illustration of the superior seagoing qualities of these barges. During one of the most severe gales we have had on the waters of the lakes, two of these whalebacks were on Lake Superior, making good weather, considering all things; for so fierce was the gale and heavy the sea, that a new schooner, in good trim, foundered in sight of the whalebacks, while the latter are here now, having weathered the storm without damage or danger. As regards our steel lake steamers, they are quite fit to encounter with safety an Atlantic storm as they are ordinarily loaded on these lakes, but if they ever come to be loaded down, like "three-deck" tramp steamers, it will, I believe, be found that their deck-houses, companions, skylights and hatches are quite unequal to withstand the seas of the North Atlantic. No fewer than 41 British steamers were lost during the one disastrous month of December, 1872, the most serious losses occurring to low powered grain laden vessels in the North Atlantic. The *Teutonic*, with a bow 32 feet out of water, is none too good to face a severe storm in that ocean.

Now, a word about the construction of these peculiar vessels. The

author, from a careful examination, would say that he has never seen better work. He would particularly notice the ballast tanks, which are most carefully planned and constructed thoughout and amongst the best he has seen in America. This is saying a good deal, for the most important feature in a steamer next to the bottom itself is the double bottom arrangement.

As regards their stanchness he would relate some facts which appear very creditable. Four of them each loaded cargoes of wheat on their first voyage and delivered the whole freight, after carrying it over 1 000 miles of stormy water, without the slightest damage. It is an uncommon thing to find any steel vessel perfectly water-tight on her first voyage, but here we have a fleet of four vessels which did not leak a drop from the beginning to the end of their first voyage. The designer may be justly proud of this achievement.

The author has long maintained that to an engineer, at least, that what is satisfactory looks well, or should do so. So when any one says, for instance: "Oh! I would not have a bow like that, it does not look nice," the reply is, "If that is all your objection it is not worth serious consideration." But let us see if it is nice. Ask any good naval architect this question as to their appearance. Look at that bow. Can you improve it by adding the ordinary dead-wood? Would such not render the vessel less handy to steer and add useless weight to her bow?

Let us examine the question of their rolling qualities. The fault with our broad lake steamers is that they have too much stability of form. This is brought about by the center of buoyancy moving out from the center too rapidly and too much as the vessel heels over. The best way of counteracting this would be to cut off the upper corners of the gunwale, or rather to curve them in just as the American steel barges are formed. This would cause them to roll much easier, or, in other words, make them better sea boats. As regards stability, it may be said that so long as the present maximum ratio of breadth to depth is maintained, there would seem to be little or no cause for anxiety about their stability even with a full cargo of grain, if fairly loaded. This is not a mere statement nor yet a deduction, for the *Charles W. Wetmore* has recently steamed across the Atlantic Ocean in ballast, without any cargo in the hold, and with over 600 tons weight of coals on her 'tween-deck beams, which are situated 16 feet above the keel.

In conclusion, the following may be cited as amongst the desirable

improvements in lake steamship construction, as being within the range of practical achievement during the next few years in this center of the world's progress in mechanical science.

First.—Greater length and breadth are necessities in steamers.

Second.—Greater simplicity in design and construction are desirable.

Third.—Deeper water ballast tanks, and bottoms to be more carefully arranged to withstand vertical longitudinal stress.

Fourth.—Top sides and upper works to be designed more particularly to resist increased stresses due to greater length in proportion to depth.

Fifth.—Hold bulkheads to be made stronger generally, and stiffened as may be required to resist the hydrostatic pressure. The bulkhead to be more efficiently connected to the shell of the vessel than generally obtains; also an improved system of bulkheading is advisable, with a view to avert sudden disaster after violent collision.

Sixth.—A more efficient system of bilge and ballast pump, suction pipes and valves is desirable.

Seventh.—Uniformity in handling or turning steering wheels is a necessity if collisions are not to increase.

Stockless anchors to stow in the hause-pipes would save labor. Shorter stroke in engines and fewer tubes in boilers would give increased efficiency.

Improved rules for the construction of steel vessels and a proper system of inspection are necessities if marine insurance is to continue a possibility with the insured and the insurer, for the ship-owner pays for the losses in the long run, the underwriter's business being a commission on the amount of loss paid; and the greater the amount of loss in the long run, the greater would be his commission on the loss.

The following statement is made by J. McArthur, Master of the *Colgate Hoyt:*

We arrived here last night and will leave here to-night. We were just eight days in making the round trip with consort, and we laid twelve hours at two harbors. We find in running alone that our average fueling, for three trips, was 122 tons per trip. In towing consort we made our trip with 140 tons. I think this is very economical on fuel. We tow about 11½ miles per hour light, and 9¼ miles loaded.

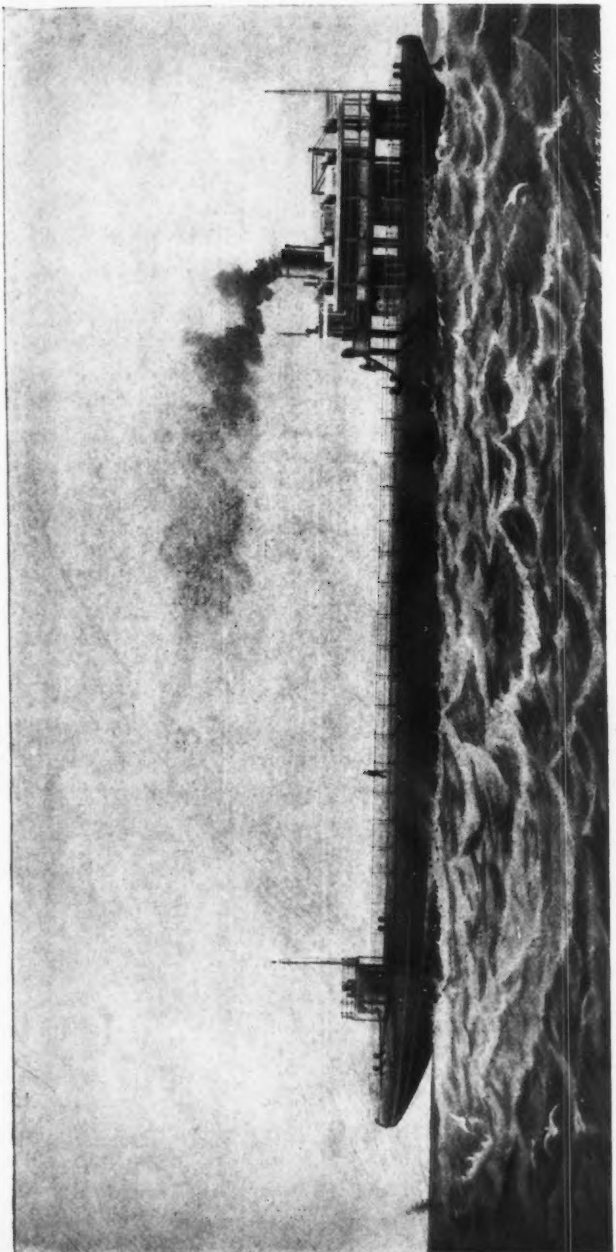
NOTE.—Plate LXXXIV and LXXXV are the only ones showing details which the author has been able to obtain. Plate LXXXIII gives a good general view of one of the boats.

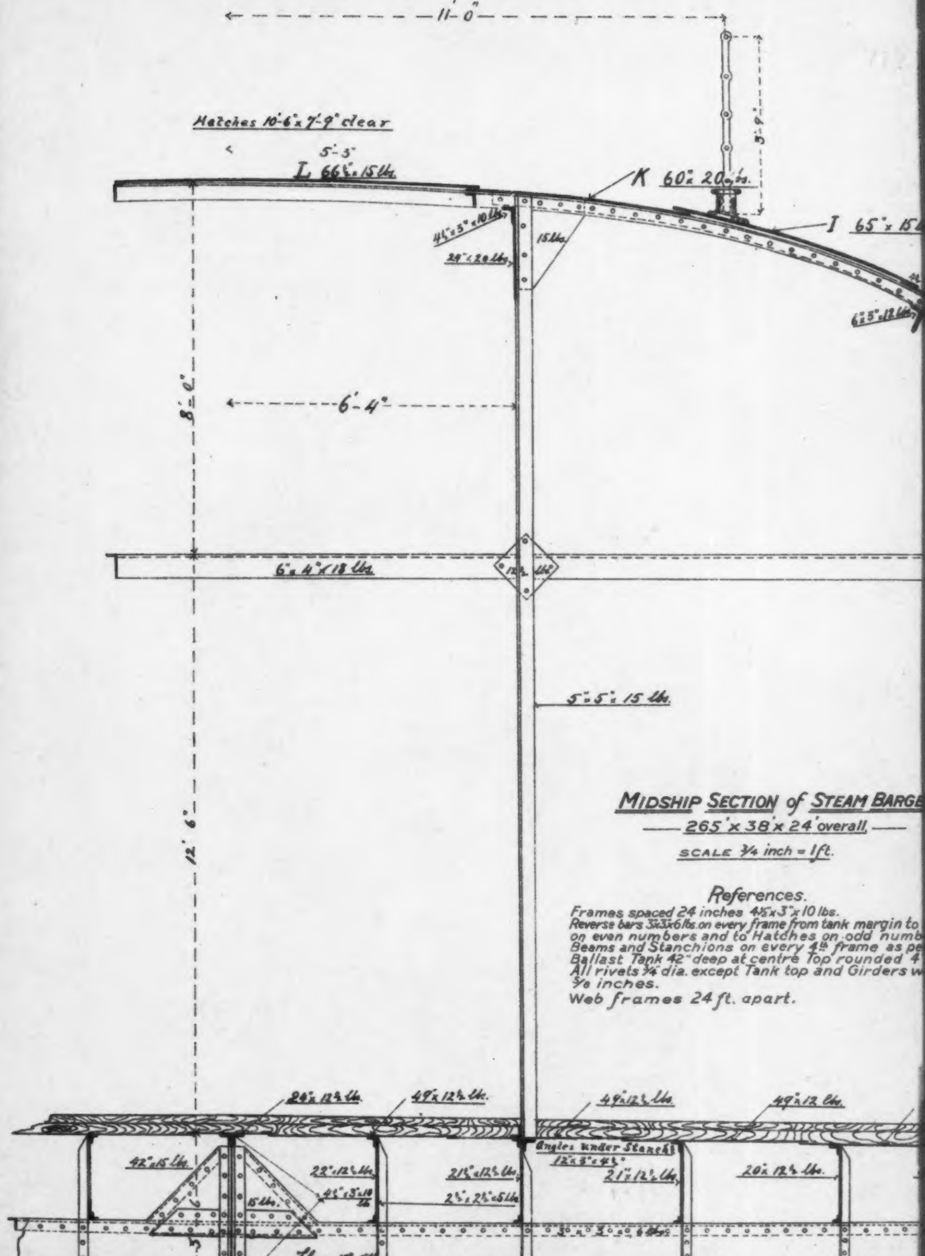
GENERAL PARTICULARS, SPEED AND EFFICIENCY CONSTANTS OF SEVERAL TYPICAL SCREW STEAMERS.

NAME.	Length.	Breadth.	Depth.	Draft.	Tonnage V. D.	Displacement.	Horse-power.	Speed per hour.	Constants.
	Feet.	Feet.	Feet.	Feet.		Tons.	I. H. P.	Knots.	$\frac{D^{\frac{2}{3}} \times S^3}{\text{I. H. P.}}$
Teutonic* .... M	565.8	57.8	39.2	26.0	8 829	13 000	17 000	20.18	267.3
City of Rome .... M	560.2	52.3	37.0	21.4	7 468	11 230	11 890	18.235	255
City of Paris .... M	527.0	63.0	39.2	....	8 570	12 500	20 100	21.952	283
Servia .... M	515.0	52.1	37.0	23.3	7 212	10 960	10 300	17.00	234.3
Etruria .... M	501.5	57.2	38.2	22.5	7 129	9 860	14 320	20.18	260
Oregon .... M	501.0	54.3	38.0	23.7	7 017	11 000	13 300	18.30	227.9
Columbia .... M	463.5	55.6	35.5	....	....	10 106	12 850	19.77	277
Britannic .... M	455.0	45.2	33.7	23.0	4 757	7 000	5 400	16.00	277
Tyne .... G	319.0	34.0	26.0	18.0	....	3 445	1 194	11.59	297
Jubilee C	300.0	40.0	27.5	23.8	2 230	5 800	1 360	10.00	237
Mariska .... L C	300.0	40.0	24.5	14.0	....	4 100	1 234	10.9	268
Brunswick C	246.0	33.0	18.0	18.0	1 132	3 000	650	9.0	234
Bathhurst .... T	130.0	13.5	....	4.0	....	75½	1 230	24.453	213.9

* Steamed 21.54 knots per hour average speed for twenty-four hours. The I. H. P. would be about 20 700 to attain this speed.

N. B.—Class of steamer: M, mail steamer; C, cargo steamer; L C, lake cargo steamer; G, Government steamer; T, torpedo boat.





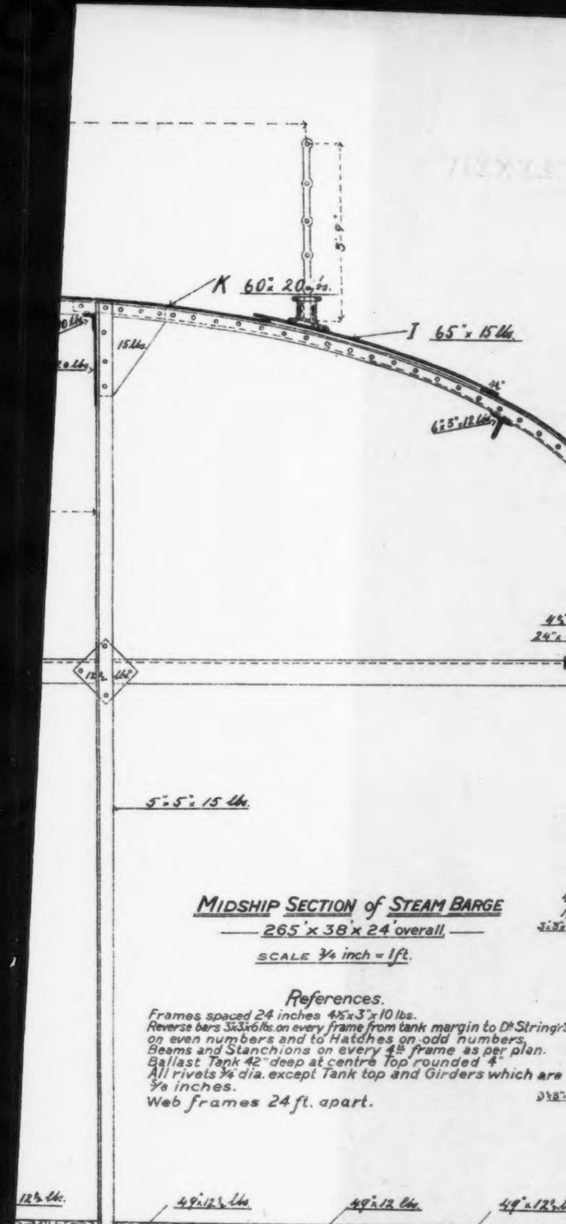
MIDSHIP SECTION of STEAM BARGE

265' x 38' x 24' overall.

SCALE ¾ inch = 1 ft.

References.

Frames spaced 24 inches 4½" x 3" x 10 lbs.
Reverse bars 3" x 3" x 6 lbs. on every frame from tank margin to
on even numbers and to Hatches on odd numb
Beams and Stanchions on every 4th frame as pe
Ballast Tank 42" deep at centre Top rounded 4
All rivets ¾" dia. except Tank top and Girders w
⅝ inches.
Web frames 24 ft. apart.



K 60" x 20 lbs.
3' 9"
I 65" x 15 lbs.
15 lbs.
20 lbs.
5" x 5" x 15 lbs.
MIDSHIP SECTION of STEAM BARGE
265' x 38' x 24' overall
SCALE 3/4 inch = 1 ft.
References.
Frames spaced 24 inches 4½" x 3" x 10 lbs.
Reverse bars 3" x 3" x 6 lbs. on every frame from tank margin to Dk Stringr
on even numbers and to Hatches on odd numbers.
Beams and Stanchions on every 4th frame as per plan.
Ballast Tank 42" deep at centre Top rounded 4"
All rivets 3/4 dia. except Tank top and Girders which are
7/8 inches.
Web frames 24 ft. apart.
12½ lbs.
49" x 12½ lbs.
49" x 12 lbs.
49" x 12½ lbs.
Angles under Stanch's
12" x 3" x 4½"
21" x 12½ lbs.
21" x 12½ lbs.
20" x 12½ lbs.
30" x 12½ lbs.
2½" x 2½" x 5 lbs.
A 65" x 20 lbs.
B 65" x 20 lbs.
C 65" x 20

PLATE LXXXIV.
TRANS. AM. SOC. CIV. ENG RS.
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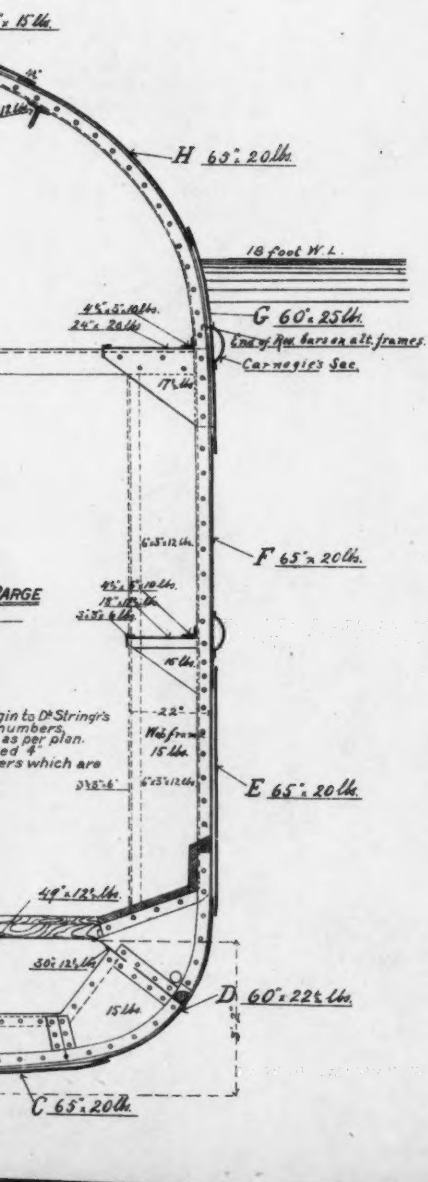
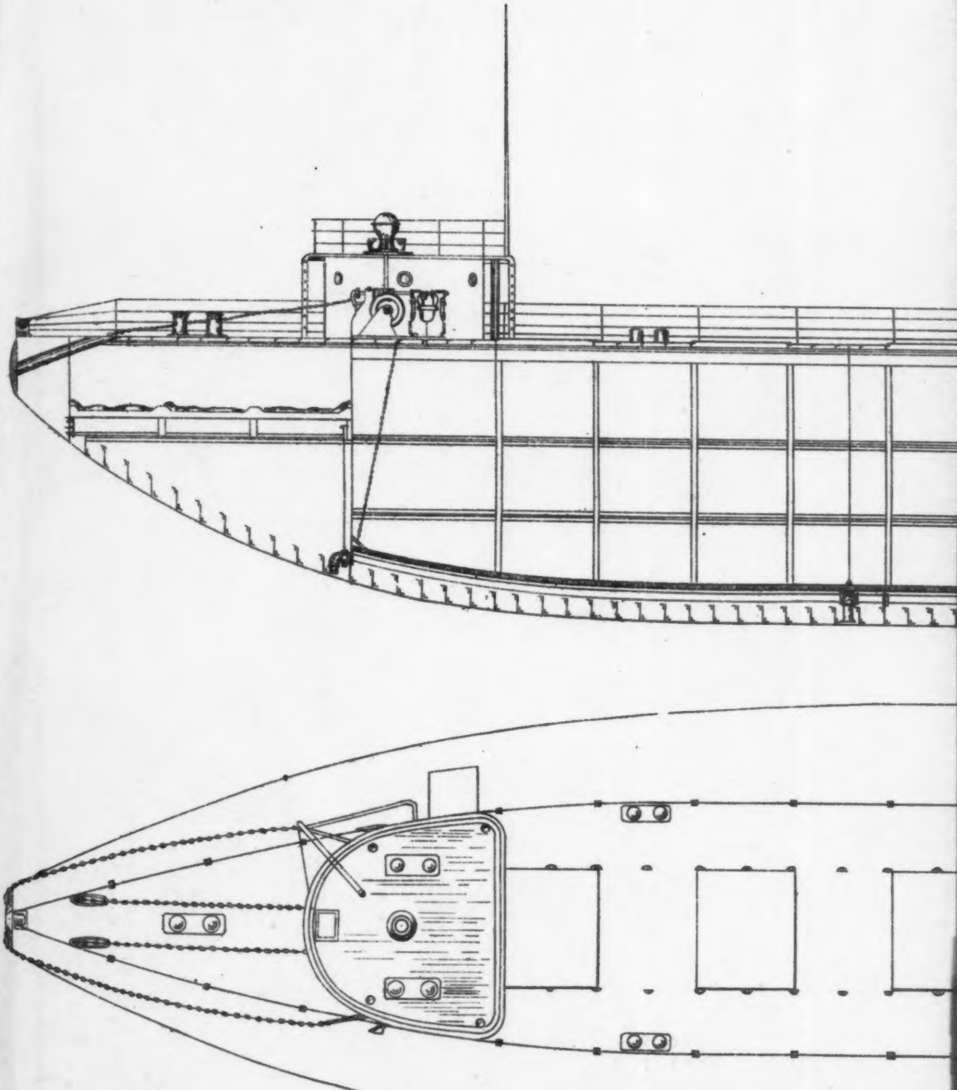
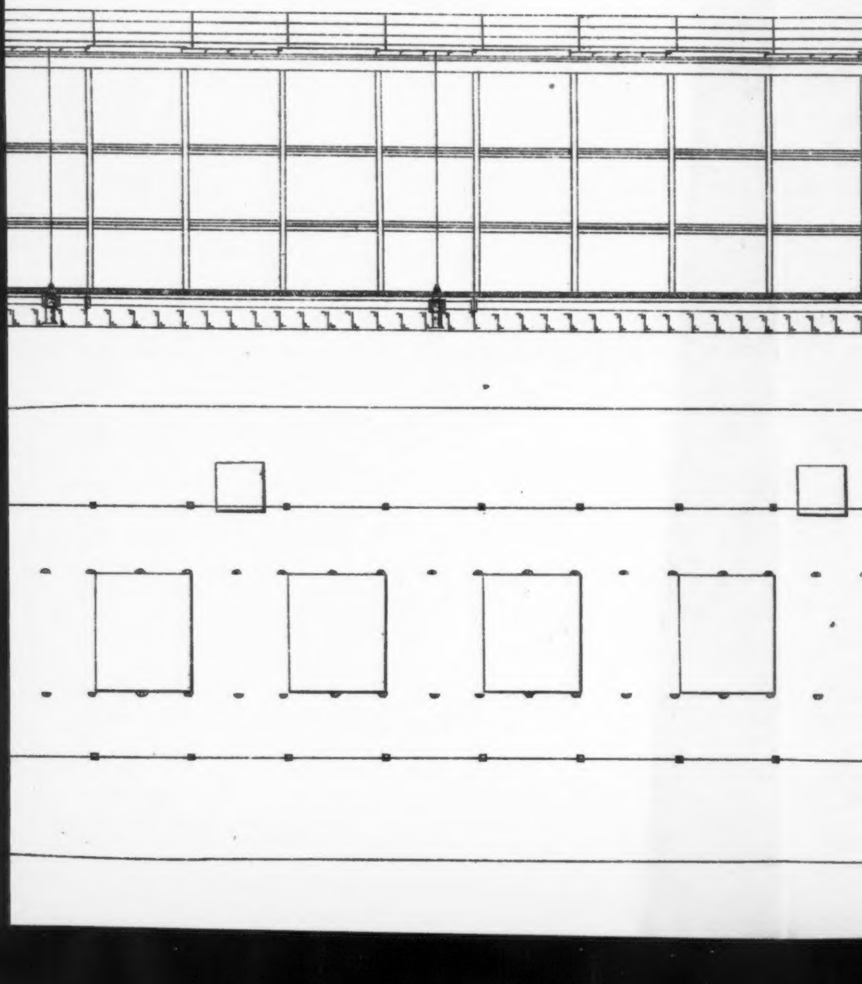
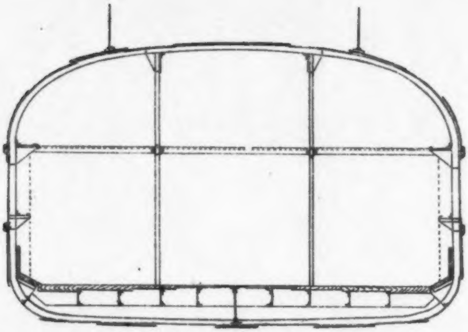
OLDHAM ON
WHALEBACK STEAMERS.

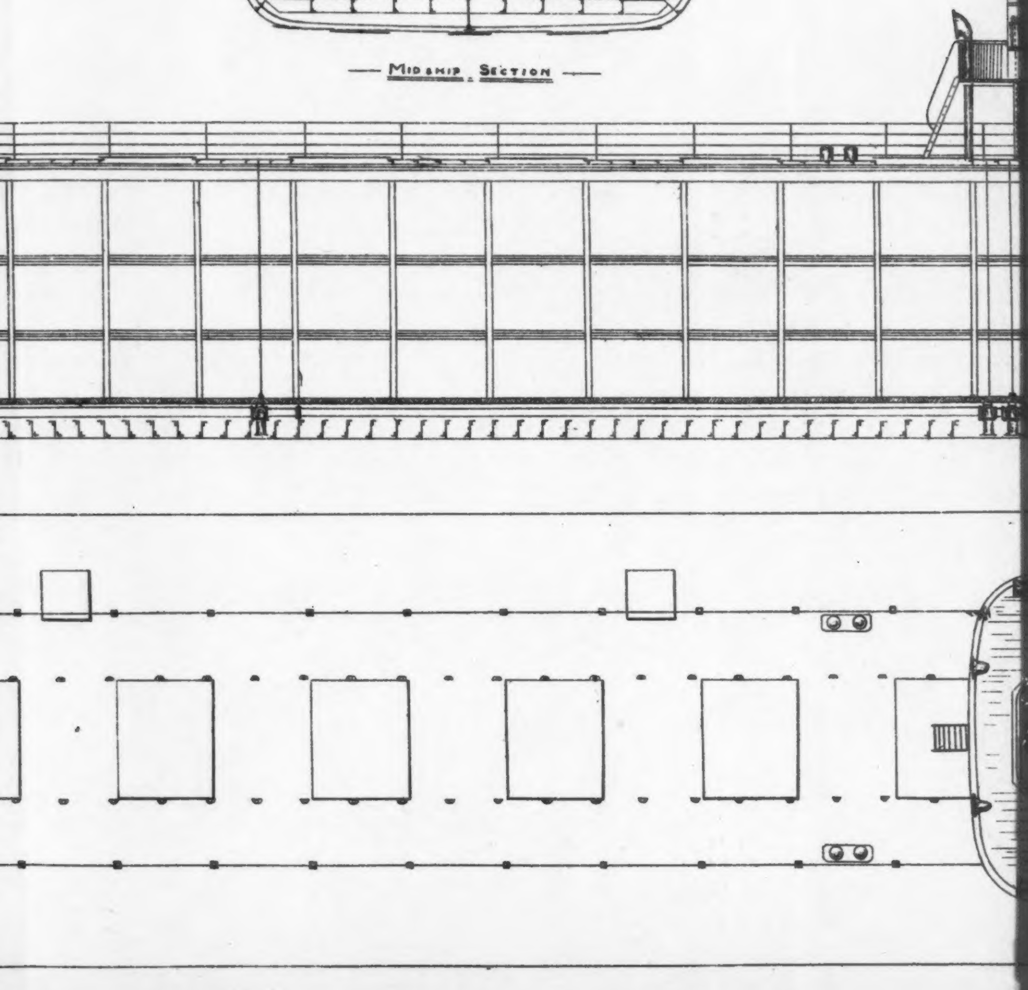


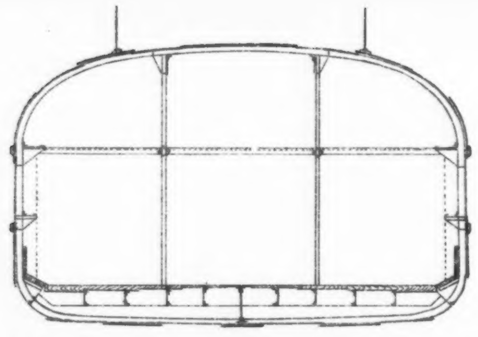






— Midship Section —





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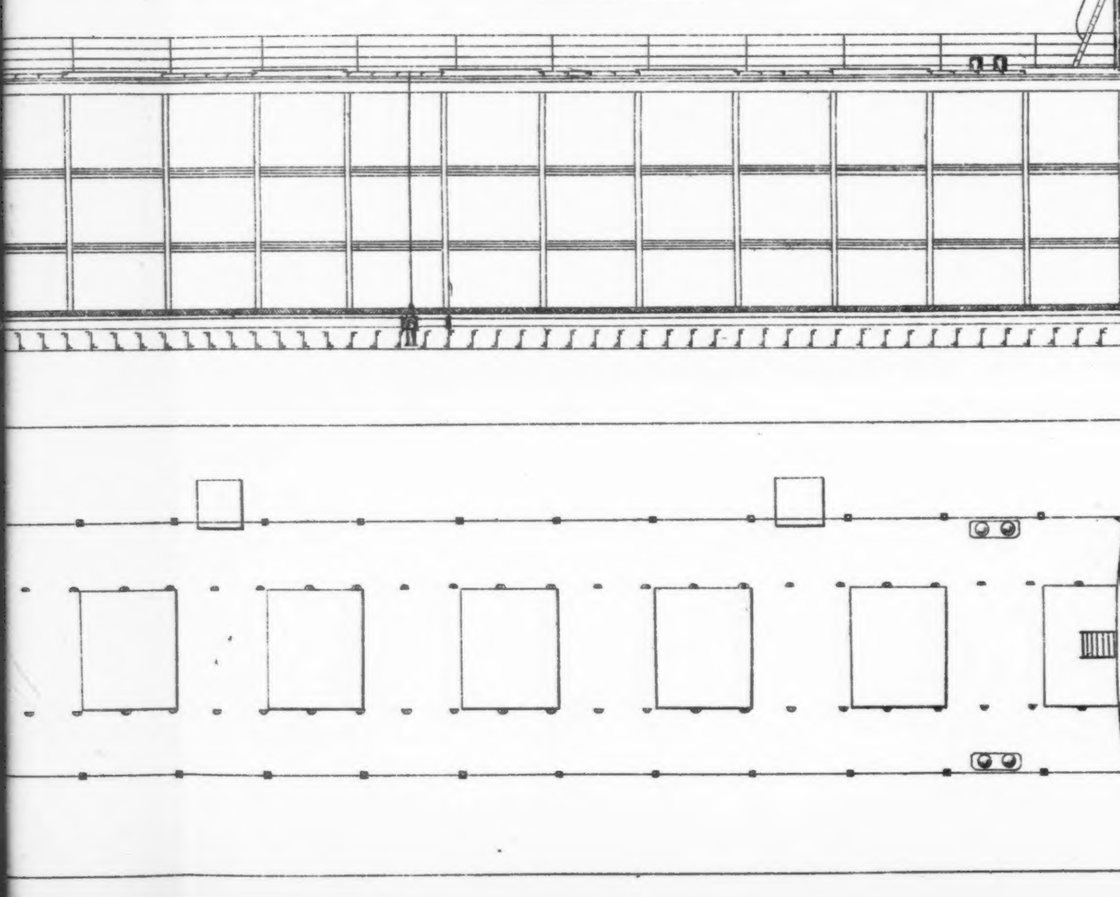
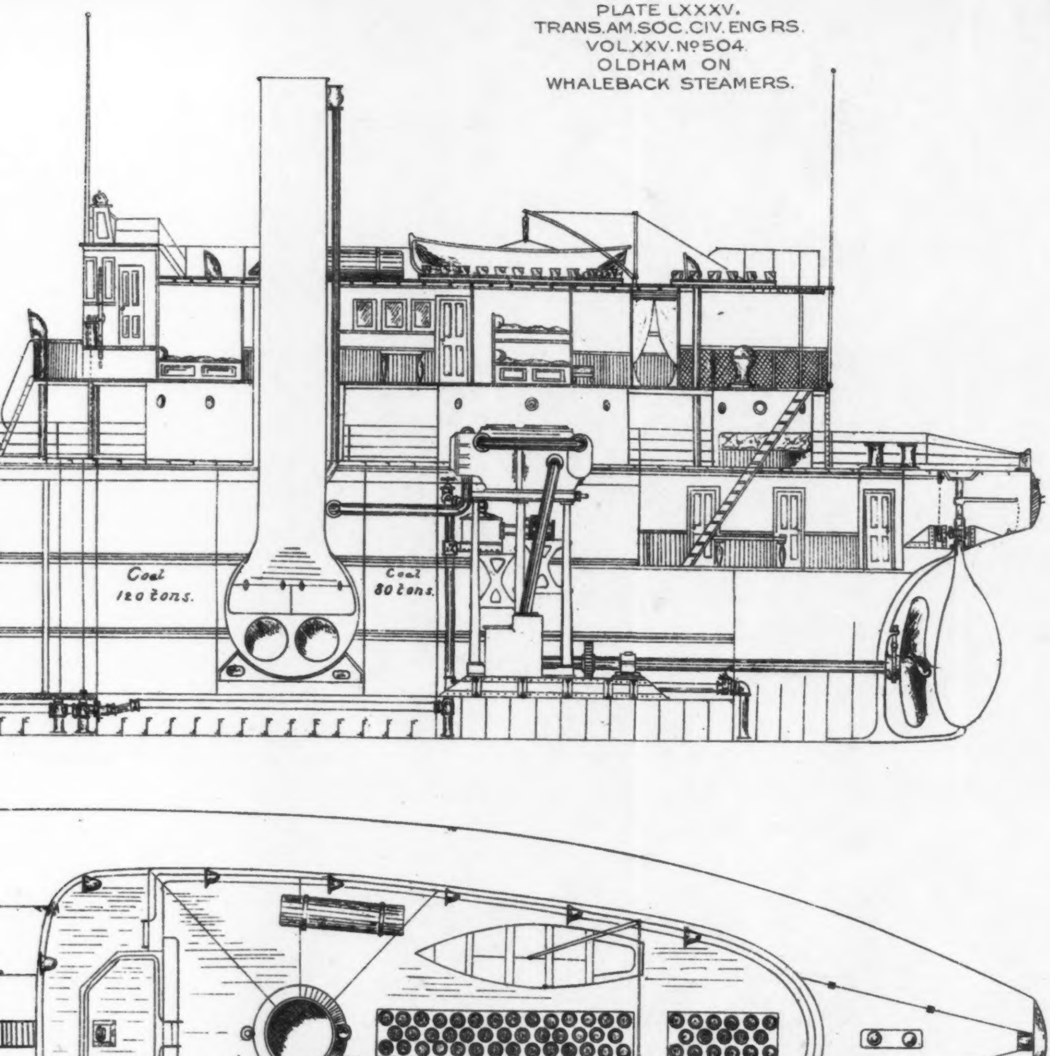


PLATE LXXXV.
TRANS. AM. SOC. CIV. ENG RS.
VOL. XXV. No 504.
OLDHAM ON
WHALEBACK STEAMERS.



Also the following by Alexander McDougall, General Manager of the Steel Barge Company:

The *Colgate Hoyt* carries about 2 200 gross tons on 14 feet of water, and the consort referred to—107—carries 2 450 gross tons on the same draught, or each of them will carry 23 tons to the inch after that. Their maximum draught for good sea-going would be about 16½ feet. They are both the same size. The *Hoyt* has run 16 miles an hour the entire length of the lake several times and 12½ miles loaded. Her consumption of fuel and the good results obtained I think beat anything on record. Her engines are 26 and 50 x 42-inch stroke; boilers, two 11 x 11½ feet—125 pounds steam.

DISCUSSION.

Charles E. Emery, M. Am. Soc. C. E.—To judge accurately of the performance of the vessels it is necessary to know the indicated horse-power and some further details of the engines and boilers. It is also desirable, from an economical point of view, to know the amount of coal consumed. Hoping to obtain more detailed information on this subject I wrote Mr. Frank E. Kirby, the engineer of the Detroit Dry Dock Company, and inclose his reply, which may be of interest.

My dear Sir:

Yours of the 23d inst. at hand. I have only been at home three days during the past two weeks. I regret that I am unable to furnish you any particulars of the whaleback engines, and there is so much misinformation about their performance that what is seen in the public prints is valueless. I have glanced through Mr. Oldham's paper. The high efficiency he claims for the *Sitka* and tow of whalebacks is true with tows of any kind of vessels.

With regards, I am yours truly,

Frank E. Kirby.

Herbert C. Felton, M. Am. Soc. C. E.—Referring to "Advance Copy" of Mr. J. R. Oldham's paper on "Screw Steamships and Tow Barge Efficiency, etc.;" the enclosed clipping, taken from the Philadelphia papers of to-day's issue in regard to the "whaleback" steamer *Charles W. Wetmore*, may be of some interest from a practical point of view as regards the cost of loading and discharging when in a port where suitable shore conveniences might be limited. In this case the dredge was moored between the pier and steamer, and, of course, occupied additional dock-room and consumed more time in handling freight.

"The work of loading the much-talked-of whaleback steamer *Charles*

W. Wetmore was completed yesterday, and at daylight to-day she will begin her 13 000 mile journey to Port Townsend, Washington. Stevedores are not sorry the arduous task of loading the oddly-constructed craft is over. They say she is not constructed to carry cargoes of machinery, being without spars or any tackle by which the huge blocks of machinery can be hoisted into her capacious hold. It was necessary to secure the services of a dredging machine to load her."

Geo. S. Morison, M. Am. Soc. C. E.—I have nothing to say in the discussion, but I would call attention to the fact that the note as to the speed of the *Teutonic*, on page 12, is hardly correct. I was on board of her when she made her longest run, which was 517 knots from noon to noon in twenty-four hours and forty minutes, or a little less than 21 knots per hour. This would correspond better with the indicated horse-power actually developed.

J. A. Ockerson, M. Am. Soc. C. E.—Mr. Oldham's paper on "Screw Steamship and Tow Barge Efficiency on the Northwestern Lakes" comes at a very opportune time. The success of the "whaleback steamers" seems to have been thoroughly established and a new era in shipbuilding on the "Great Lakes" has begun. On a recent visit to these "inland seas," I was informed that several of the large shipyards were practically idle, as far as new work was concerned, awaiting the results of a thorough trial of the "whalebacks."

I hope the discussion on this paper will bring out more fully the details of construction of this new form of freight carrier.

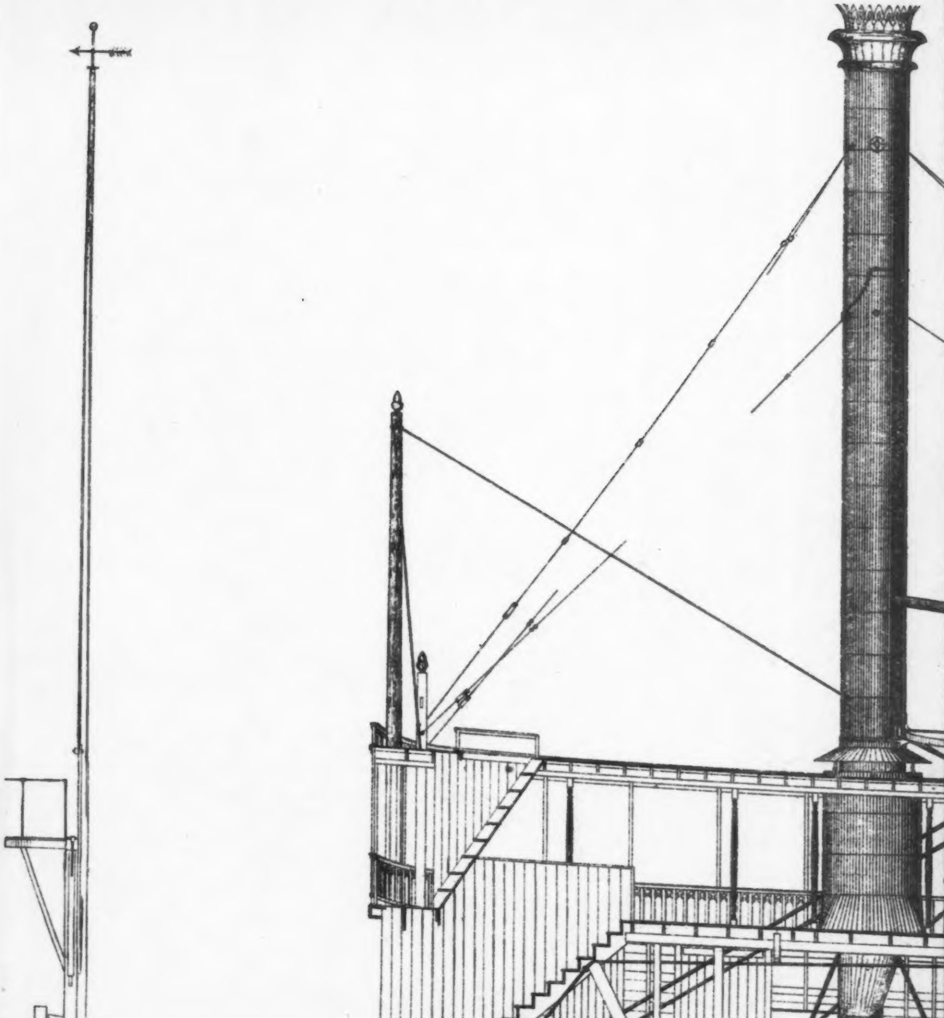
On the Mississippi River but little progress has been made in the methods of steamboat construction, except, perhaps, in the tendency to use steel instead of wood for the construction of hulls.

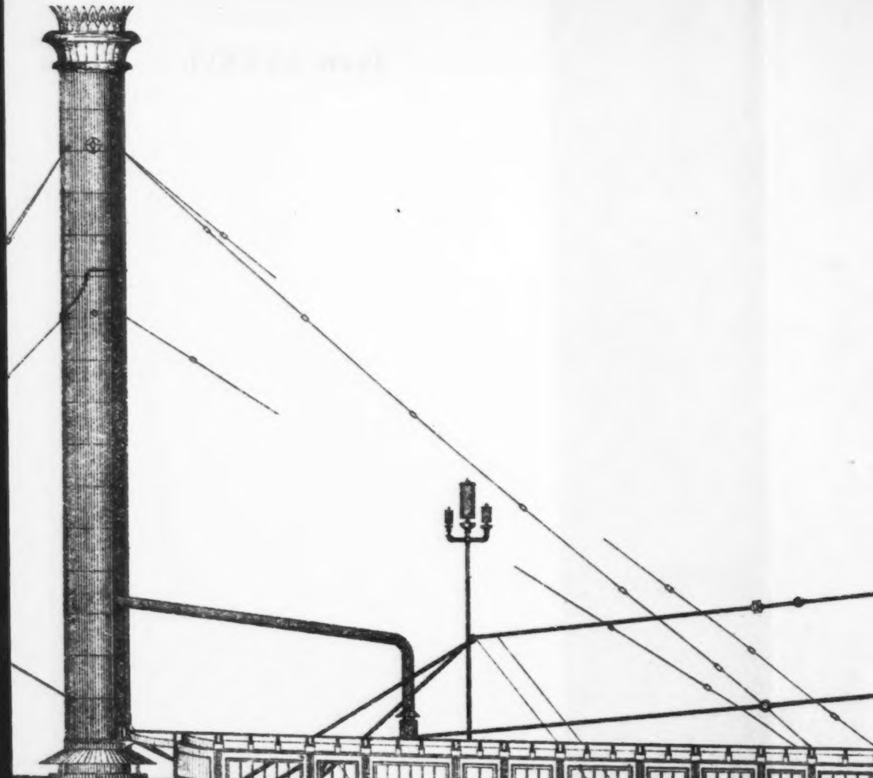
I take this opportunity to present a drawing of the Mississippi River Commission tow-boat *Minnetonka*, used in towing barges loaded with rock and other material from points above the Ohio River, to the improvement works carried on by the Commission on the lower river. (See Plate LXXXVI.) The general description of the boat and its machinery are as follows.

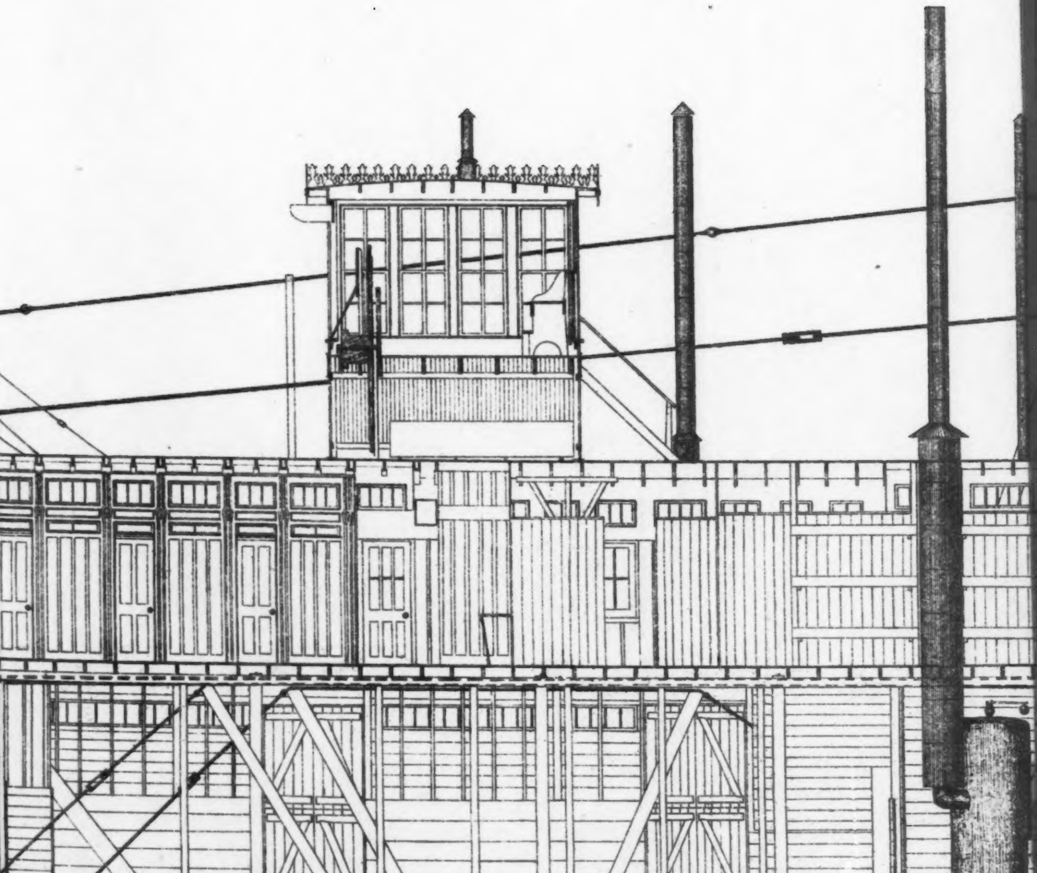
Length from forward nosing to splash bulkhead	176 feet 5 inches.
Length to end of fantails	202 feet 9 inches.
Width over all	35 feet 4 inches.
Width inside at top of floors	29 feet.
Depth of hold	5 feet 4 inches.
Crown of beam amidships	6 inches.

Draught.—When loaded with 1 500 bushels of coal the boat draws 4 feet 7 inches forward and 3 feet 4 inches aft, one-half of the coal being in the forward bunker.

Planking.—The bottom plank are 3½ inches thick, the knuckle 4 inches, and then planking becomes gradually thinner to the cutting







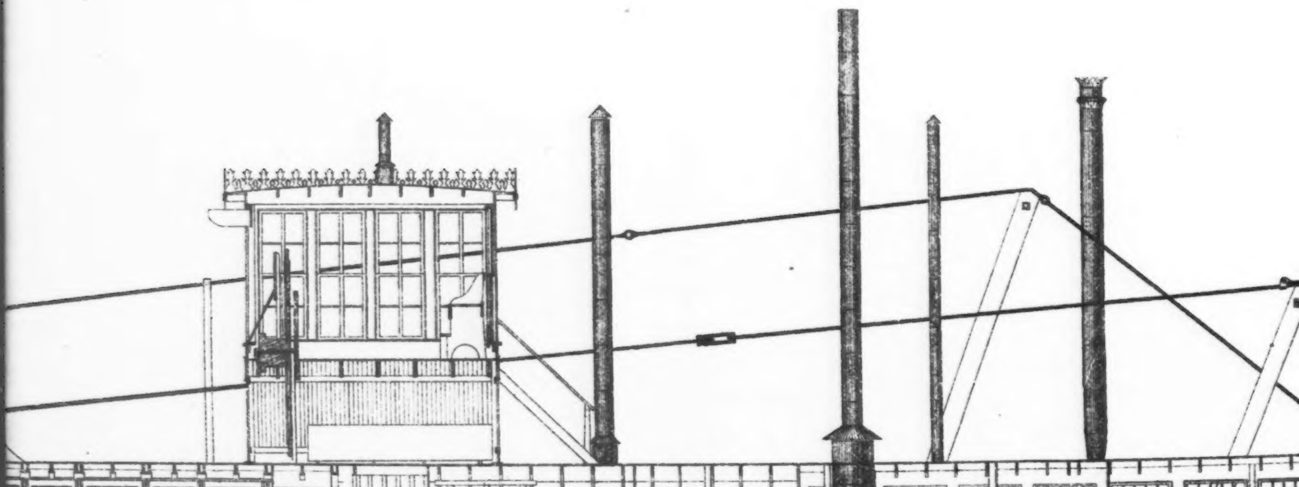


PLATE LXXXVI.
TRANS. AM. SOC. CIV. ENG'RS.
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OLDHAM ON
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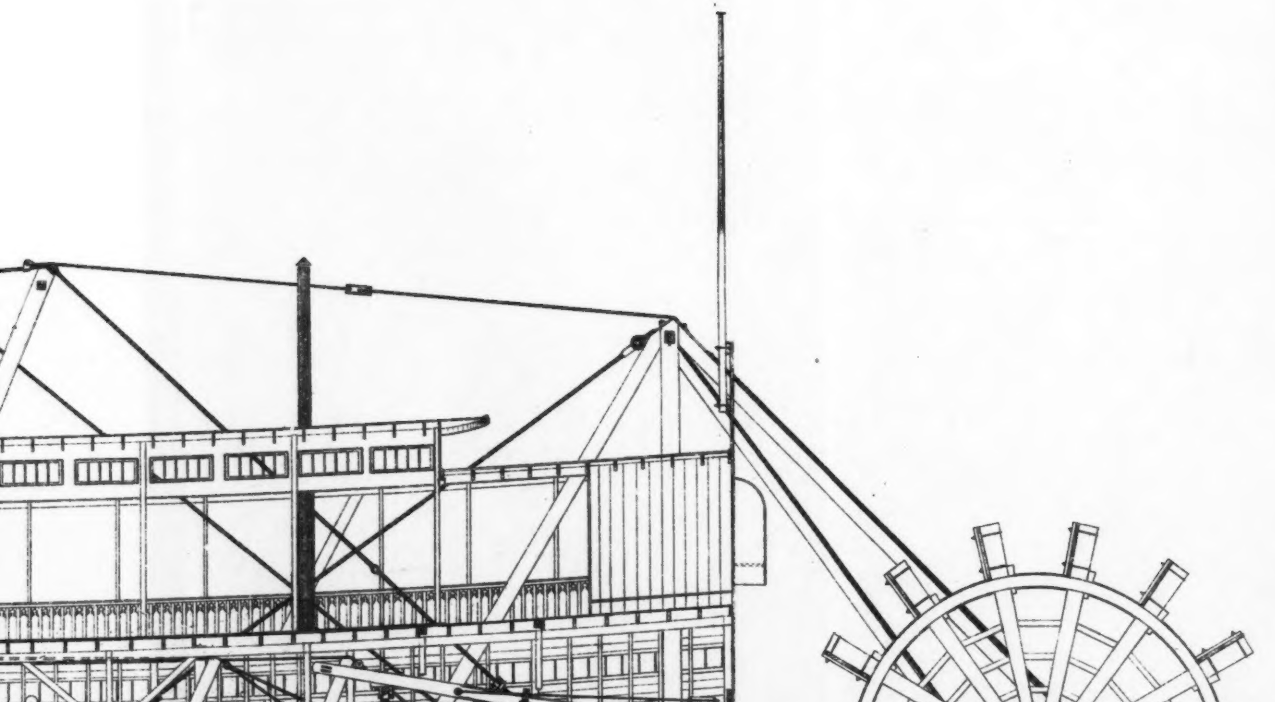


strake, which is $2\frac{1}{4}$ inches thick. The height between main and boiler decks is 11 feet 6 inches.

BOILERS.—There are four return flue boilers 44 inches diameter, 26 feet 6 inches over the heads, made from steel $\frac{26}{100}$ inches thick, having 45 per cent. ductility and 70 000 pounds per square inch tensile strength, and each one has two flues of 12 inches and two of 14 inches diameter, and is double riveted throughout. There are two mud drums 15 inches x 16 feet $2\frac{3}{4}$ inches long. There are two steam drums 20 inches in diameter, and 16 feet 4 inches long. The steam pressure allowed is 165 pounds.

FIRE BOX.—The grate bars are 5 feet $2\frac{1}{4}$ inches long over all, by $3\frac{1}{2}$ inches wide, with a middle slot 1 inch wide, and a maximum depth of $4\frac{3}{8}$ inches; the tops are $20\frac{1}{2}$ inches above the ash pan, and $17\frac{1}{4}$ inches below the bottoms of boiler shells.

The grate area is 81.75 square feet; the total heating surface 231.2 square feet; and total tube area 2 136 square inches.

ENGINES.—The main engines have cylinders of $22\frac{7}{16}$ inches inside diameter and 8 feet stroke. The steam ports to cylinder are $8\frac{3}{4}$ x $3\frac{3}{8}$ inches, and exhaust ports $9\frac{3}{16}$ x $3\frac{1}{4}$ inches. The poppet valve is used for steam and exhaust. There are also reversing engines, electric engines and capstan engines.

PUMPS.—There are the following pumps, viz., the "doctor," the donkey pump and the bilge pump.

SHAFT.—The stern wheel shaft is made of iron, hexagonal in section, and its dimensions are 13 inches x 25 feet $10\frac{3}{4}$ inches. The cranks are 4 feet from center to center. The pitman is 38 feet $3\frac{1}{2}$ inches long, a section at the middle being $7\frac{1}{8}$ x 20 inches. It is built up of pine with iron straps top and bottom, 5 x 1 inches, bolted through with $\frac{3}{4}$-inch bolts.

R. H. THURSTON, M. Am. Soc. C. E.—The new departure in ship construction, referred to in the paper of Mr. Oldham, is one of exceptional interest; but I think that it involves no new principles and develops no previously unfamiliar facts in the department of naval architecture and marine engineering. The experiment now being tried on so large and satisfactory a scale, simply illustrates the general principle that in marine engineering, when prompt delivery of freight is not important, the costs of transportation are made least by adopting a low speed. That this principle has a limit is probably very true, but this limit is found at some extremely moderate speed. When it is remembered that the power demanded to impel any vessel, at speeds for which its form is well adapted, varies as the cube of the speed, and that the cost in steam for work so done varies between the two termini of a given route, as the square of the speed, and inversely as the square of the time of transit; it becomes obvious that high speeds are enormously costly and that low speeds are correspondingly economical. Again, the modern steamship, as commonly built, is adapted for the best service in mixed traffic. It must be equally satisfactory as a conveyer of passengers and of freight,

and its freight may be either the so-called "fast freight," which can be assessed heavily for costs of transportation, or the freights of iron, steel, grain and cotton, which may just as well be transported at low speeds and delivered a comparatively long time after shipment. Such a vessel is adapted especially to neither one nor another of these diverse and contradictory purposes; and it consequently and naturally can do neither kind of work to best advantage and with maximum economy and profit to its owner. Build the ship for a single trade, and it becomes at once possible to attain previously unexampled economy.

Thus, the fast steamers in the transatlantic trade should be made passenger and "express" freight boats simply, and the McDougall steamer illustrates the same principle precisely, in being constructed in such manner as to be well fitted for exactly the reverse case, heavy freights at low velocities. Taking the speed of the former as 20 knots, its tonnage at its load displacement as 10 000, and its power as 2 horse-power per ton at its average speed; the same tonnage, in any hull equally well-shaped for the lower speed, could be driven at 8 knots by about one-sixteenth that power, or about one-eighth horse-power per ton, or 8 000 tons 8 knots an hour with 1 000 horse-power. At 7½ knots, the figure for power becomes about 600 horse-power, or a little better than is here reported for the *Colby* when towing "nearly 8 miles an hour" (7½ knots), and better than the *Sitka* is reported to have done. But the figures for the *Sitka* have no value, except as rough approximations, in the absence of any actual "indication" of the engines and a trial of engines and boilers. The rule for "nominal" horse-power gives no reliable gauge of the actual power of the machinery or of its efficiency or losses and wastes. The estimate of power demanded by the Rankine formula, based on ship resistances, is more likely to be closely approximate and may be taken as a probable result. It is not at all out of the way in itself, or as requiring any remarkable quality of boat to meet its figures. The co-efficient, 247, for the displacement formula, is not at all high; in fact, it is rather low for these times. The fuel account is good. The figure originally, I think, given by Mr. Forney, as representing the performance of good ships on the ocean, a half ounce of fuel per ton transported, per mile, at a 10 knot speed, is the equivalent of $\frac{1}{2} \div 16 \times 100 = 3$ pounds nearly, or less than that here given for the "whaleback," which exceeds the ocean steamer in consumption of fuel by 66 per cent. This standard is a remarkably high one, however, and the lake boat's performance is probably fully up to the average of ocean-going craft.

The self-trimming construction of these boats is a good illustration of the advantage which comes of the freedom gained by the naval architect, when he may design for a single and specifically characteristic work. The ordinary case is one in which decks for passengers and working decks for the men, must be provided. Here, discarding sail power, the "tumble home" of the old *Constitution* and her contemporaries of the

early part of the century is readily carried further, and far enough to permit this self-stowage of the grain which is expected to be the common freight of these vessels. The design seems to me to be an admirable illustration of a courageous and sensible working out of a specified problem, unhampered by custom or convention. This form of section also promotes seaworthiness, as claimed by the writer of the paper, and as does anything which permits the sea to pass over and by the ship, instead of breaking against her sides or on her decks. I was once for a year on duty on our largest and heaviest "monitor" iron-clad, built during our civil war, and I never spent a more comfortable year when at sea (and I have been in all kinds of ships, month in and month out, at all seasons on our Atlantic coast and elsewhere) than on the old *Dictator* monitor. I have known a claret bottle to stand by the hour (empty) on the messroom table when a gale of wind was blowing overhead, the seas sweeping where they chose, but never causing noticeable rolling. In this ship there is, I presume, as there should be, some passage below decks, fore and aft, for stormy weather; and below decks, I should expect it to be, as claimed, thoroughly comfortable in the heaviest weather, and should anticipate, as a common result of the same formation of hull, impunity, so far as the ship is concerned, in passing though the heaviest gales. This point is, to my mind, certainly a good one, and a most important one. I like also the double bottom and water-ballast arrangement. I have experienced its good qualities in earlier years at sea, and am confident that it will prove satisfactory, if properly constructed and handled.

The seven conclusions with which the paper concludes seem to me to be thoroughly correct, and a most excellent statement of essential principles in this class of construction, and, in the main, for naval construction generally. The advantages which the oval section and ellipsoidal form of these vessels offer in providing opportunity for strengthening the upper line of the beam—for the ship is to be considered a beam subject to all sorts of vertical, transverse and longitudinal stresses as well—are well worth considering, as is their advantage in simplicity of construction, small cost and superfices, with large capacity and minimum skin resistance.

The one thing remarkable in this case seems to me to be the fact that shipowners and a naval archtiect have been found, having a sufficient independence and originality to work together in the solution of a simple obvious problem, unhampered by either precedent or apprehension of criticism, professional or unprofessional. I was attracted by the original designs of Captain McDougall, years ago, when he was endeavoring to introduce his fast ship with its singular section, and have been glad to see that he has taken up a more promising line of commercial work, and with such prompt success. As lake freight steamers, I imagine they will be found admirably suited for their work, and I shall not be surprised if they ultimately find permanent place in the transatlantic trans-

portation of slow, heavy freight. I would congratulate the captain and his friends on the success thus far attained.

Charles H. Haswell, M. Am. Soc. C. E.—This paper is rendered interesting by the recital and some of the results furnished, and if I entertain the claims of the writer correctly, he advances several claims to superiority of this new type of vessel. Also, that this type, which is designated as "whaleback," affords "extraordinary speed," together with "large capacity and enormous dead weight ability," and that the speed of one of them is claimed as "somewhat phenomenal." Further, that they are exceedingly staunch, tow with ease and small consumption of fuel, roll easily, and that their stem is of an outline to produce the least possible destruction in the event of a collision. Now, in order to consider or concur in these very desirable qualities, one properly looks to discover the particular elements and features whereby their attainment, so boldly asserted, is supported, and to present this subject to those who are not familiar with this peculiar construction or type of vessel, I submit: In outline its submerged portion approximates to that of a semi-elliptic spindle, whilst the upper portion or freeboard has "tumbled-in" sides, with a curved flush deck and quadri-circular junction to the sides of the hull, with light iron stanchions, and wire rope or rods around the sides in place of a heavy rail and close bulwarks, without spars and rigging. As regards their alleged speed, there is not a single element furnished showing whereby greater effect is attained than there would be in a hull of the ordinary form, with like or equal areas of section, ease of lines and proportional power.

As to "capacity" and "dead weight ability," I fail to recognize how such a type of hull furnishes greater capacity, either for bulky cargo or dead weight; quadri-circular top sides not only do not present a single advantage, but in loading with light freight the space lost by such conformation of sides is lost to stowage. Neither is it shown how they furnish "capacity" in excess of any other vessel of the usual proportions and constructed of like materials; neither does any such advantage as it is claimed exist, as equal volumes give equal capacity and like weights like displacement.

Staunchness, which is also claimed for them, is dependent upon the proportionate dimensions of a hull and the integrity of its construction, and as this quality is attained in the very greatest number of vessels of ordinary design, I equally fail to recognize the justice of the especial claim submitted by the writer for this type over that of other unrigged vessels.

Concerning their navigation, it is also claimed that the absence of the ordinary top-gallant forecastle, deckhouses and like constructions on the spardeck, enables them to offer less resistance to wind and seas, and as a result their operation is more effective; on the other hand, I advance that the flush deck, protected only by an open iron or wire rail, renders

manual operations on deck in stormy weather wholly impracticable; and that erecting the wheel-room, cabin, berthing, galley and all deck requirements upon columns several feet above the spardeck, presents more effective resistance to the wind than the deck constructions of our ordinary freighting steamers; added to which the facility afforded to the boarding of seas and the retardation occasioned by their impact more than offsets the advantage claimed.

Inasmuch as there are not any elements given why they should tow with great ease and with greater economical consumption of fuel than other vessels, I am at a loss to consent to an operation that bears upon its face a negation of the axiom that like causes produce like effects. As the form of stem of a vessel is arbitrary with the designer, and as in practice it is presented in every practical outline, I am further at a loss to recognize any individual claim to the outline given or any advantage in a form of bow, not water-borne for a long distance, and hence subjected to the stress of the weight of anchors and chains upon it in a pitching sea.

Regarding their rolling qualities and stability, both of these operations depend upon form of immersed section of hull and location of center of gravity of the mass; and the conformation of one and the location of the other cannot be essentially affected by cutting off the upper corner of the gunwale. If the *Charles W. Wetmore* in her late voyage across the Atlantic in ballast had not had stowed the 600 tons of coal between decks she would have rolled and lurched to a degree that would have rendered her crew much pleased to make a port; hence that which is claimed as a merit was indispensable to safety of the vessel.

In conclusion, a review of all the elements submitted and claims advanced does not present or substantiate in any one instance an advantage over that of an ordinary and well constructed freighting steamer of like displacement and power, and alike without spars or rig; subject to the question, if such absence of spars is at all practicable with the requirements of safety of the vessel and crew.

JOSEPH R. OLDHAM, N. A.—With reference to the discussion on this paper I would say, that possibly in my effort to hit upon a terse title for my paper, I have made it obscure, for as I make use of the word "efficiency" in that title, I do not intend it to be limited to the expression for performance as regards horse-power and speed, but I use it in its more general or ordinary sense, as denoting general efficiency, with slight particular reference to seaworthiness.

In reply to your learned member, Mr. R. H. Thurston, I may say that there was no opportunity for actual "indication" of the engines and boilers of the *Sitka.* As to losses and waste, I freely admit that with such facilities as ordinarily exist on board of cargo steamers at any rate, that I lack the courage to assume what such losses may be, for I verily believe that marine engines will require much more careful indi-

cating than has as yet been done before I may know what the waste and losses amount to in the ordinary triple expansion engine; but then I am only a practical shipbuilder and marine surveyor, and my paper has no pretensions to being an exhaustive treatise either on the speed of screw steamships, or on the maximum power of marine boilers or power as indicated in marine engines.

My conclusions were based on certain practical results observed under ordinary conditions at sea, and my deductions give indications of maximum ability with regard to the working of common machinery in common use. The formula for horse-power is distinctively put forward as approximate, and I have found such very useful, when hurried estimates were required for steamers to carry a certain dead weight of cargo at a required rate of speed.

The co-efficient 247 may not be very high, but these are every day results with one fireman cleaning and feeding four large furnaces for six hours at a time, or with "watch and watch"; they are not trial trip figures, which obtain for a few hours only, it may be, and are never resuscitated, but as they are they indicate higher efficiency than the *Brunswick*, 234, *Queensland*, 203, at about the same speed, or the *Africa*, 173. Professor Thurston says my figures are "rather low for these times." I am rather of opinion that they may be low as compared with old times, for nearly all the old freight steamers I can call to mind were much finer models than the modern "tramp" steamer; and these, I think, would not compare unfavorably with the *Great Britain*, if similarly rigged, or the *Propontis* or *Delaware*—of course I mean apart from coal consumption. I sometimes imagine that our models, except in very high speed vessels, have deteriorated, like our poetry. I think it is hard to make good verse in these days, and with the conditions usually imposed on our shipbuilders, they say it is hard to make a nice model.

Allow me to say in reply to Mr. Charles H. Haswell, that the form of the *Whaleback's* bow is such that about 700 feet of surface is saved by cutting away the dead-wood or fore-foot, and this with but slight reduction in dead weight ability; and thus on the skin friction theory of resistance the *Whaleback* should steam as fast as a steamer of the same dead weight ability, with about 5 per cent. less propelling power; again, her extremely narrow stern may increase the speed co-efficient, and the unincumbered decks will do so in a head wind. Like weights certainly do give like displacements, but like displacements do not always give like dead weight ability.

These vessels up to the present time are of similar proportionate dimensions to the ordinary lake steamer, which admittedly and unavoidably has excessive breadth of beam, giving them too much stability of form. The bold tumble-home in the "whalebacks" reduces the length of the righting lever to a desirable extent, and thus lessens the shock at

large angles of inclination. The rolling qualities of ships are most certainly directly and severely affected by other portions of hull than the immersed section when upright.

Does Mr. Frank Kirby mean us to understand that in his opinion the ordinary lake tow barge will tow as easily as a "whaleback"? Then why are the latter being towed for about 25 per cent. less money? I would be pleased to concede the point of error claimed by Mr. George S. Morison in connection with the steamphip *Teutonic*. I was not at sea in this case, however; I will gladly amend my figures if Mr. Morison will be a little more specific, so that my correction may be reliable. In conclusion I may state that I have never been commissioned by Captain McDougall or other officials of the American Steel Barge Company either to champion or defend their property. My paper was intended to be an impartial investigation into a novel type of steamer, and I trust that in that respect it has not wholly failed. It was my duty to survey and report on these vessels for, and to, the "Record of American and Foreign Shipping." After considerable anxiety I concluded that these peculiar vessels merited the highest class in the highest record of shipping, and so they were recommended and classed. Some people said that they would smother the crew, others said they would "turn turtle," others again prophesied all these calamities and much more. Now about the prophets. For three seasons these vessels have worked all over these lakes. One has crossed the Atlantic twice with impunity, another has "rounded the Horn," and many people are at this moment paying Captain McDougall the sincerest flattery summed up in the word imitation.

NOTE.—The author requests the following changes to be made on this page: Line 3, for "surveyor" read "engineer"; and in lines 23 and 24, for the words, "and these I think would *not*, etc.," read "and these latter I think would, etc."

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

505.

(Vol. XXV.—October, 1891.)

THE SINGLE TRAP SYSTEM OF HOUSE DRAINAGE.

By LATHAM ANDERSON, M. Am. Soc. C. E.

WITH DISCUSSION.

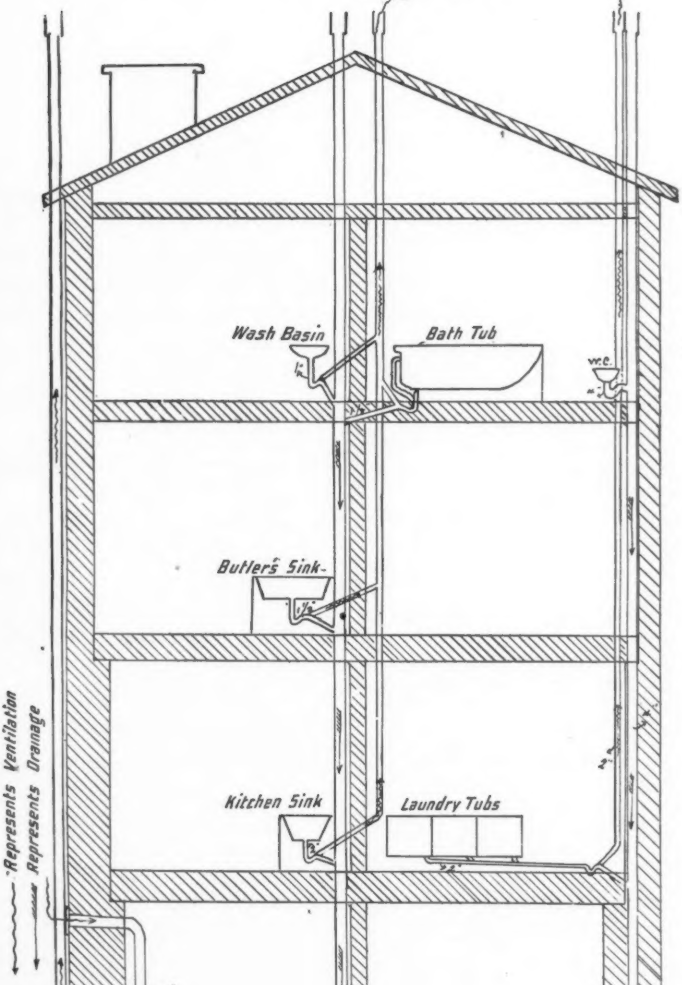
The most approved system of house drainage now in use embraces the following features (See Plate LXXXVII):

A.—A main trap in the sewer branch where it leaves the house, either immediately inside or outside of the outer wall.

B.—A vent the same size as the sewer branch, connected immediately outside of the trap, and extending either on the outside, inside, or within the house wall, above the level of the roof ridge. This outside vent is seldom applied or required by State laws or city ordinances; but is, in my judgment, the most important feature of the system. The objection urged against the introduction of this feature is, that in the case of the first house to introduce it, the sewers of the whole neighborhood will be vented at this point, and hence the said house will be plagued with more than its share of sewer air. It is true that under such conditions, there would be a constant rush of sewer air up the vent. But even so, the condition of the house would be improved. Such a vent could not fail to lessen the pressure of sewer air on the down-stream side of its own trap,

PLATE LXXXVII.
TRANS. AM. SOC. C. E.
VOL. XXV, No. 505.
ANDERSON ON HOUSE DRAINAGE.

Present System



so that when water was passing through the trap, less sewer air would bubble back into the house. It is a prevalent popular fallacy that a water seal ever completely excludes sewer air.

Whenever water is discharged from a pipe or vessel containing air at a certain pressure, into a pipe at a higher pressure, air from the latter will invariably bubble back into the former, especially toward the latter end of the flow. This holds true whether a trap has been introduced or not. I have frequently observed this bubbling, even in a Bower's trap, which is closed by a rubber ball. Now such a vent as above described, must lessen the sewer pressure, and therefore correspondingly lessens, if not altogether prevents, such bubbling. At any rate, such a condition should not be allowed to occur for any length of time, because every house should be required to have such an external vent-pipe. Take the case of a solidly built city block, 400 feet long, with houses of 25 feet front, on each side, giving thirty-two houses in all. With a 12-inch sewer, 6-inch connections (as required in Cincinnati and most other cities), and 6-inch vent-pipes, the following ratio would exist between the sectional area of the main sewer and the aggregate area of all the vents. The area of the 12-inch sewer is 113 square inches; that of the vents 32 x 28¼, or 904 square inches; in other words, the total area of the vents would be eight times that of the sewer, so that with four house connections on each square, *i. e.*, two on each side of the street, the area of the vents would equal that of the main sewer. With an 18-inch sewer the area is 254½, or less than a third that of the vents. But in the opinion of many eminent engineers, 4-inch branches are much better for houses of ordinary size than 6-inch. With 4-inch branches and vents, the ratios would be as follows: For a 12-inch sewer as 113 is to 402, and for an 18-inch sewer as 254.5 is to 402. Hence it is apparent that under this plan, even with 4-inch house branches, it would be impossible for any abnormal pressure to exist in the same sewer. Even in the case of the 18-inch sewer, the venting would be ample, because it is doubtful whether any appreciable pressure ever exists in as large a pipe as this, in a properly designed system of sewers. The internal pressure is considerable only in the small pipes at the upper ends of the system. Hence, if these be thoroughly vented and ventilated, the larger and lower parts of the system will take care of themselves. It should be noted in this connection, that especially in long and large sewers, there is frequently a downward and outward flow of

air at the outlet; while there is invariably, as far as I am informed, a strong upward flow or pressure of air toward the upper openings or traps at the bottom of the system. The higher pressure at the latter points is increased and maintained by the inflow of hot water from baths, laundries, etc., which keeps the upper and smaller pipe sewers constantly at a higher temperature than the larger and lower parts of the sewer. Hence there must be some intermediate parts of the system where the sewer air is stagnant and without pressure, or even where the outer air flows into the sewer through the various vents. Another case is sometimes cited as an objection to outside vents. This is where a low house is hemmed in by much higher ones. Here, it is claimed, the air from the lower vent will ascend into the upper windows of the higher houses. This would undoubtedly be the case, if there were no vents on the upper houses; but with all the houses on the sewer outside vented, the preponderating upward flow of air must always be through the highest pipes—following a well known law of the flow of gases. Where the vents all act as down-casts (as above described), of course no inconvenience would result to either house. In some cases it might even happen that the lower shaft would act as a down-cast, at the same time that the air was ascending in the higher vents. But I freely admit, that in order to provide against all possible accidents, and to remove feelings of apprehension in the minds of the dwellers in the higher houses, the top of the vent of a lower house should never be allowed to terminate below the roof level of a higher one adjoining it. It could easily be carried along the wall of the higher house; as chimney flues usually are under like conditions. If the system of vents above described possesses the superior advantages herein claimed over any other system of sewer ventilation, it would be the height of folly to abandon it because of the slight and easily removed obstacles just specified.

C.—Another feature now required in all advanced practice, is a fresh air inlet carried from outside to a point just inside of the main trap.

D.—Every internal branch of the soil-pipe is carried full size, and as straight as possible, through the roof.

E.—Every fixture must have a separate trap of its own.

F.—In addition, every kitchen and butler's sink must have a grease-trap. From a sanitary point of view, this is one of the most essential features of house plumbing. Without it, grease from the dishes adheres to the inner surfaces of the pipes and especially of the sewer branch out-

side the house. This, in time, accumulates to such a degree that the pipes are frequently plugged solidly with grease and adherent trash, and they are always filthy and foul smelling to the highest degree.

G.—Every trap and dead space in water-closets must be separately vented at the top of the outer bend, the branch vents connecting with the main vent.

H.—A separate vent-pipe carried up as straight as practicable through the roof, and not, as is usually done in Cincinnati, into the upper part of the soil-pipe below the roof. The McClellan Anti-Siphon Trap Vent is designed to take the place of this complicated system of trap vent-pipes, and seems to answer the purpose admirably. It is approved by Colonel Waring, and the author is informed, has been accepted in lieu of vent-pipes by the sanitary authorities of New York and other Eastern cities. But, while it seems to possess decided superiority over the vent-pipe system, and to perform its functions perfectly while in order, he does not think it can claim to give absolute immunity from sewer air, because of the possibility of its becoming injured. For instance, the small pin which acts as a guide to the cup may be caused to move stiffly or to stick fast in its ring by corrosion or by the freezing of vapor attaching to it in very cold weather.

I.—Vent-pipes must never be carried on the inside of a fire-flue.

K.—Water-closets must never be flushed by direct connection with the water supply pipes, but must be provided with intercepting automatic tanks.

L.—House leaders for roof water, must not be connected directly with the sewer branch.

M.—All joints must be air-tight, and, of course, the materials and workmanship must be of good quality.

N.—In the best practice, all pipes are exposed and not sunk in the masonry, nor covered by plaster; being so arranged that they are everywhere accessible for examination and repair. Recently this has been made compulsory in some of the most advanced sanitary regulations.

The above provisions embrace the essential features of plumbing now required in the sewer connections of houses, exclusive of the water supply and of steam or hot-water heating.

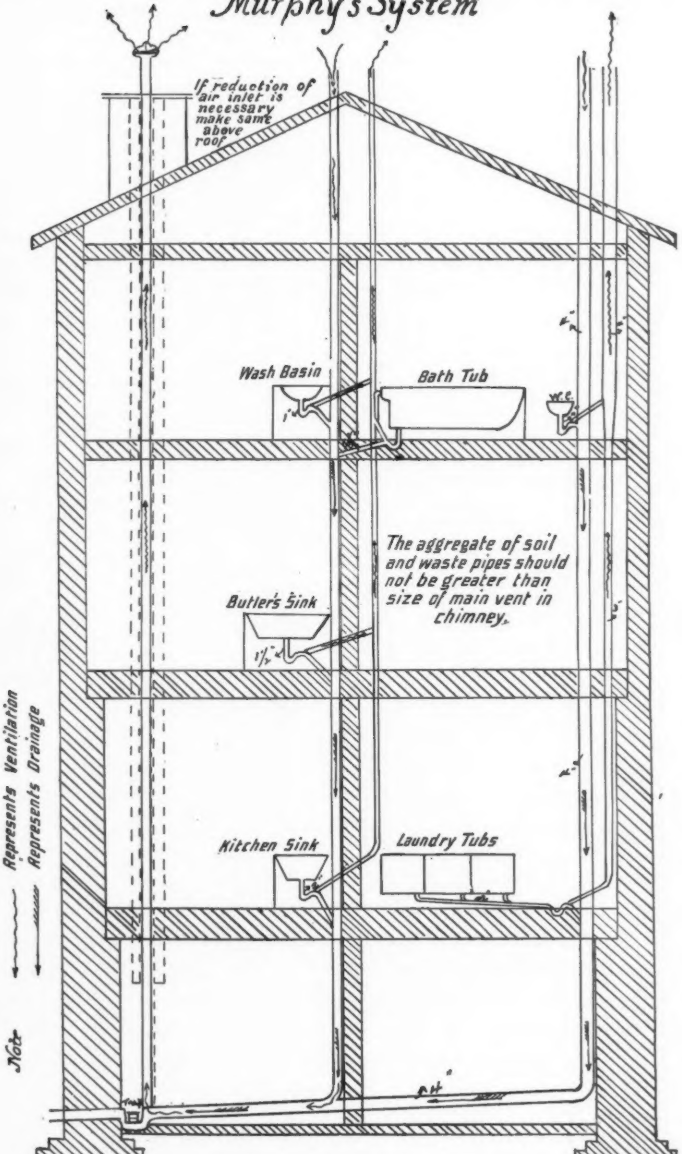
Dr. E. S. McClellan, the inventor of the trap above mentioned, truly says, "Notwithstanding the commendable progress of recent years in house sanitation, the most approved methods of house drainage still have

defects, dangers and complications that call urgently for correction and simplification." If this be true of the most approved methods, the "defects, dangers and complications" of house drainage as it actually exists, in conformity with sanitary regulations, and as above described, are still more glaring. The following are some of its main defects:

First.—Considered as a system of ventilation it is complex, unscientific and uncertain in its action. One reason of this irregularity of action is that the air currents in the soil-pipe are descending, and would, therefore, be reversed in their direction by descending currents of water.

Second.—For reasons above described, but few, if any, houses are exempt from the entrance of sewer air. In cold weather this intrusion of sewer air is further facilitated by what has been termed "the house suction" of heated buildings. The place of air exhausted by chimney and other hot-air flues must, of course, be supplied by an equal amount of air entering through other channels. This causes the outer air to be sucked in at every crevice. According to Pettenkoffer this suction is so strong as to draw an appreciable amount of air through solid brick walls, except where they are painted, or the plastering is unusually dense. The colder the weather the greater will be the difference between the inside and outside temperatures, and the stronger the house suction. Therefore, under these conditions, more sewer air will be sucked into the house.

Third.—The numerous local traps form lodgments for filth. The constant presence of water in the traps through the house keeps the inside of the pipes continually moist, and therefore in a condition to promote organic decomposition and the propagation of germs. This is true whether the air in the pipes be stagnant or in motion; for, in the latter case, evaporation progresses rapidly from the water in traps. As a matter of fact, dampness and consequent foulness is the normal condition of waste-pipes, especially near their respective fixtures. It results from these conditions that by far the most filthy and noisome parts of existing sewerage systems are the plumbing pipes within houses, and, except where grease-traps are not used on kitchen sinks, the standing wash-basin is the nastiest feature of the plumbing. In improved appliances, especially in the simple outlet made by the Sanitas Company, the theory is that readily accessible parts will always be kept clean. In practice this cleanliness is more the exception than the rule, the appliances usually becoming and remaining foul after being in use for a short time.


Murphy's System
If reduction of air inlet is necessary make same above roof
Wash Basin
Bath Tub
W.C.
The aggregate of soil and waste pipes should not be greater than size of main vent in chimney.
Butler's Sink
Kitchen Sink
Laundry Tubs
Note
Represents Ventilation
Represents Drainage

Fourth.—The water in the traps left unused for a considerable time evaporates, thus destroying the seal. This would occur in the case of fixtures not regularly used—the basins in guest chambers, for instance, or throughout the house when it is left unoccupied for some time, as when the family are absent for the summer. Under such conditions, the rooms in question, or the entire house, become a main vent for the sewer; all the hangings, carpets, clothing in drawers and trunks, etc., being saturated with sewer air, provided the flow of the air in that part of the main sewer is toward the house ; *i. e.*, that the vents are acting as upcasts. The latter may or may not be more dangerous to health than the foul air within the house-pipes, according as there are or are not recent cases of infectious diseases in any of the houses using that part of the sewer.

Fifth.—The object of back-venting is to prevent the water in the traps from being forced or siphoned out by the discharge of other fixtures attached to the same soil or waste-pipe. If the pipes were always properly designed as to size, direction, bends and other structural details, such breaking of the seals could be effectually prevented by this contrivance. But this perfection is rarely attained in practice, so that it is probable there are few houses exempt from siphonage at some points.

Sixth.—Back-venting is conducive to one evil, so serious that many sanitary engineers and plumbers object to it altogether, preferring, as a choice of evils, the retention of stagnant, impure air within the pipes. This defect is, the increased rate of evaporation of trap water caused by the constant passage of air through the vent-pipes. According to Dr. John S. Billings, U. S. A., evaporation enough to break the seals "will occur" in two months, if the trap is not ventilated, and in about two weeks "if it is ventilated." Hence the evils mentioned under objection 4 would occur more quickly and surely in an unoccupied house with back-venting than without it.

Seventh.—In very cold weather the house air contains more moisture than that out-of-doors, even when the house is warmed by furnaces (convection) or steam radiators, in which case the air is hardly ever as moist as it should be. But even then, the warm house air usually contains so much moisture that its dew point is higher than that of the outer air. The upper ends of the metal vent, soil and waste-pipes being in the outer air, they will, of course, have the same temperature as the latter.

Consequently the watery vapor from within will be condensed on the inner surfaces of these pipes as it approaches their upper ends. When the outside temperature is very low this condensed moisture freezes, so that, in many cases, the pipes become completely plugged with ice, and the ventilation is cut off at the very time when the house suction is strongest, and when, as explained in No. 2, there is greatest danger from the entrance of sewer air. This condensation also aids in maintaining the internal moisture of the pipes noted above.

Eighth.—This tendency of sewer air to force its way into the house demands that every joint of the pipes shall be air-tight. This perfect tightness of every joint is rarely attained, if in fact it be attainable in practice. Even where the joints are air-tight when first made, there are several causes tending to produce subsequent leaks; among others, settlements of the building; injuries to the pipes by other workmen who follow the plumbers; unequal expansion and contraction of the pipes, especially where this is not properly provided for in the plans; repeated concussions or jarring of the floors and walls, especially in warehouses and buildings containing machinery; and the corrosion of pipes due to the condensation noted in No. 7. A case under this head recently came under the observation of the writer. A 2½-inch spiral riveted vent-pipe to a basin was carried up behind the plastering. The pipe projected slightly beyond the furring. The man who nailed on the laths, nothing daunted by this small obstacle, removed it by mashing the pipe, so that it was flush with the furring. This slightly cracked the pipe, so that corrosion by the water of condensation finished the job by boring a hole through the pipe. Through this orifice water trickling down the pipe flowed out in such quantities as to saturate the plaster and rot the lathing. The water was so contaminated by sewer air that it was as offensive to the smell as that from any other part of the plumbing.

Ninth.—The complexity of the system, and the extent of vent-piping required, renders it costly to construct and maintain as compared with a simpler plan.

Tenth.—The so-called "fresh-air" inlet, as usually constructed, is a burlesque on the name. "Foul" or "ground air inlets" would be a more accurate title. The outer opening is rarely more than a foot or two above the ground or pavement. Frequently it is let in flush with the surface of the sidewalk, and sometimes near the curb line.

As shown by the experiments and opinions of Dr. Angus Smith, Professor Ripley Nichols, of the Massachussets Institute of Technology; of Drs. Parkes and Bowditch, of Boston; Buchanan, of England; Pettenkoffer, Simon (the noted English sanitarian), and many other scientists—"ground air," *i. e.*, air within the ground and immediately above its surface, is much more impure and injurious to health than that obtained even a few feet higher. Hence, it is radically wrong to place a fresh-air inlet on or near the ground.

Mr. Richard Murphy, a plumber, of Cincinnati, has devised a system of plumbing intended to remedy some of the above defects of the existing system. The object especially sought is to cause the air and water currents to pass in the same direction within the pipes. This is effectually secured, under favorable conditions, by the following simple and ingenious device. From a point in the soil-pipe, just above the main trap, a vent-pipe is carried to a chimney flue and carried thence inside the flue to its top. The other (local) vent-pipes are carried out through the roof, as in the present system. In order to prevent any of these from becoming up-casts, the tops are throttled, so that the aggregate sectional area of all the inlets shall be only equal to that of the main vent-pipe. All local traps and other fixtures are as in the prevalent system. When properly designed and executed, this plan certainly has the following merits, as claimed by the inventor (See Plate LXXXVIII):

First.—The traps are not so likely to be siphoned, nor forced by increased back pressure resulting from suddenly reversing the upper air currents in the pipes.

Second.—In the present system the upward pressure of the ascending air obstructs and retards the discharge of the liquids by the pipes; whereas, in his method, the descending air current assists, to some extent, the discharge.

Third.—In the existing plan, the ascending current of air aids capillary attraction in retaining moisture on the surface of the pipe, while a descending current assists the force of gravity in carrying the adherent moisture down the pipe. Moreover, the air introduced from above must always be drier than that ascending from the wet soil pipes below. For these reasons, the pipes in Mr. Murphy's system would always be drier, and therefore less injurious to the inmates of the house.

Fourth.—The tendency to suck the air in at the fixtures instead of forcing it out into the room, is stronger in Murphy's plan.

Fifth.—In the upper floors especially, the air, as it passes the traps, is much purer than if drawn from the soil-pipes below.

Sixth.—Considered as a whole, the plan of ventilation is simple and effective, and is based on a sound scientific method. As far as the author is informed, this cannot be said of any plan of house-drainage ventilation now in vogue. If such a complex and irrational method of ventilation as any of these latter were attempted in deep mining, the miners would certainly be suffocated. But while this system, as described and illustrated by its author, has the merits above claimed, it fails to remedy any of the other defects enumerated above. Besides, it has the following defects of its own:

First.—The main vent is carried inside of a smoke-flue. This is a glaring defect, and should never be tolerated for the following reasons:

A.—The pipe is liable to corrosion from the smoke and the joints to become loose from excessive expansion and contraction.

B.—It is inaccessible, so that when repairs are necessary they can only be made at great cost and trouble, preventing at the same time the use of the chimney during repairs.

C.—If the chimney were to be disused for a time, and the pipe leaked, the foul air would find its way into the house.

D.—When so cooled the pipes would be liable at times to act as a down-cast shaft. In which case the old system would be restored.

The main vent would only be effective as an up-cast when the temperature of the vent was so much higher than that of the outer air that the resulting differential pressure or head would be sufficient to overcome the frictional resistance of the pipes. In the case of a flue with an intermittent fire, that of the kitchen chimney of a dwelling for instance, it would often happen that this favorable ratio of temperature did not exist. A smoke flue could only be safely used to assist ventilation by carrying the vent-pipe outside the flue in contact with the heated brick-work, the pipe being everywhere accessible.

Second.—But the plan under consideration retains the most objectionable feature of the old, viz.: the retention of water-traps, the reservoirs of filth and moisture—a constant menace to health. No pipes can be kept reasonably dry or clean which contain these parts.

Third.—It does not provide for the outer or sewer vent.

Fourth.—In very cold weather, especially in upper rooms, the traps would inevitably freeze solid.

To obviate, as far as practicable, all the defects above described, the following plan, called the single trap system, is proposed, of which the essential features are (see Plate LXXXIX):

A.—The abolition of all local traps within the house, except the grease-traps to sinks, which are so arranged as not to be air-traps.

B.—The use of a single trap between the sewer and the house, an essential feature of the trap being a metal flap-valve just below it.

C.—A main up-take house vent, situated as in the Murphy system, immediately above the main trap. But it is essential to the proposed system that the upward current be unintermittent, and that the means provided for this end be simple, inexpensive and absolutely controllable by the occupants of the house.

D.—There are no inlets for outer air. The only air drawn into the pipes is that from the rooms, through the open ends at the various fixtures.

These are the four distinguishing features of this system of house drainage, and it is readily seen that it is a radical departure from present practice. The following are the merits claimed for it:

First.—The ventilation is simple and effective.

Second.—Cleanliness and consequent healthfulness. There being no standing water anywhere within the pipes, and the warm, dry house air constantly descending in them, their surfaces would be thoroughly dried and aerated within a few minutes after each using. Hence, dryness would be their normal condition. The germ-breeding slime which now coats our pipes could not form, being burnt up by the passing dry air. In other words, the drain pipes inside the house would become the least filthy and dangerous part of the sewage system; whereas, they now constitute the most dangerous and deadly part.

Third.—The dangerous air of the outer sewers is effectually excluded from the house, a result never heretofore fully attained.

Fourth.—By the universal use of the outer or sewer-vent the ventilation of the main sewers will be as near perfection as, in the judgment of the writer, it is practical to attain, and vastly better than by any other plan heretofore attempted or devised.

Fifth.—Inasmuch as the air must always be sucked into the open ends of the fixtures in the rooms, the drain pipes aid in the ventilation of the house, instead of being the main source of contamination of house air as at present.

Sixth.—The foulest parts of the house drains are the small pipes immediately below wash-stands. Under this system, these parts may be readily cleaned out by brushes attached to wires and fitting the bore, as in cleaning gun barrels.

Seventh.—General simplicity of construction and accessibility of parts.

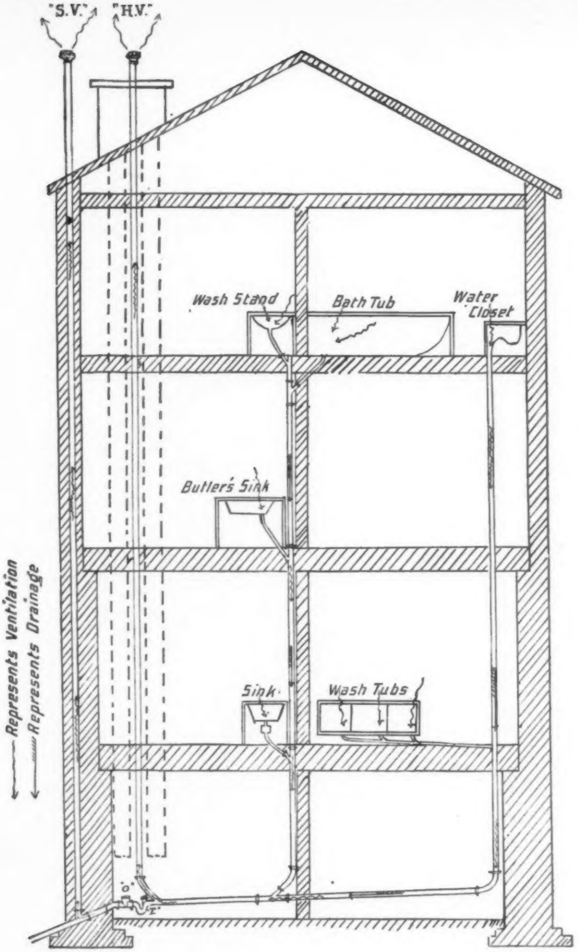
Eighth.—Owing to their cleanliness and healthfulness the various fixtures may be placed anywhere within the house without offense to the senses or danger to health, thus materially facilitating the planning and arrangement of houses in regard to the plumbing. Under the present plan, in order to avoid the serious and only partially avoidable danger to health caused by "modern conveniences," it would be good practice, from a sanitary stand-point (though rarely followed by architects), to plan the plumbing and build the house around it. Under the proposed system the plumbing could readily be adapted to any house plan.

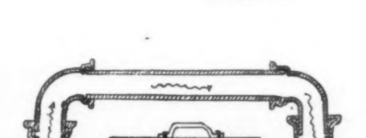
Ninth.—Inasmuch as sewer air is effectually excluded, and that in the house pipes purified, any air leaks that might exist in the pipes would not prove injurious to the health of the inmates. In view of the difficulty or impracticability of always securing air-tight joints, the importance of this ninth claim is manifest.

The most frequent objection which will probably be urged against this radical change in house drainage is that it is not automatic, but that it demands, as applied in most cases, the constant supervision of some inmate of the house, for instance, to see that the gas jet, where that is used, is kept lighted; and that where the means for forcing the upward draft in the house-vent cease to operate, the vent may become a down-cast and the air in the soil and waste pipes be discharged into the house. To these objections it is answered:

First.—That the present system, while pretending to be automatic, utterly fails in its object of securing a "dulce domum"; that the failure to supervise and cleanse its complicated and usually inaccessible parts adds greatly to its noisomeness and danger; and that the prevalent idea that it is automatic encourages this neglect and uncleanliness.

Second.—If, in the proposed system, the means for maintaining a forced draft were neglected, and, in exceptional cases, the long house-vent were to become a down-cast, the air thus admitted to the house would traverse the pipes, which, in comparison with the present wet ones, abounding as they do in miniature cess-pools, would be dry, sweet





Section Showing Connection of Grease Trap without intercepting Ventilation.

and clean. If the pipes were sufficiently coated to smell offensively, notice of the derangement of the ventilating appliance would immediately be given to the inmates, and the evil would be at once corrected. The presence of such pipe air could not possibly be fraught with as much danger to health as it would if it emanated from the present stinking plumbing fixtures or from the main sewer. In this connection, it should be noted that, as already explained, if every house were furnished with a sewer-vent, back pressure by sewer air on the main trap would be an impossibility; and that this contingency is still further provided against by the metal flap-valve. Should a house be left unoccupied for some time, and the house-vent act as a down-cast, the pipes would become thoroughly dry and aerated after the first few hours, so that they could not furnish during the entire period of vacation an unintermittent supply of foul air, such as exists in a house acting as a sewer-vent for the whole neighborhood.

The most active opposition to this reform in plumbing would probably come from the plumbers, under the idea that the amount of work required from them in order to supply a given number of fixtures would be so greatly diminished. But this is a short-sighted view. The house owner has a certain amount which he is willing to expend. If, under the new system, the plumbing for each fixture costs less—then the owner will usually add more "modern conveniences"; or, if he be an American, and has the same passion for pretentious, gaudy ornamentations as most of his fellow countrymen, he will spend the balance in polished marble, nickel or silver plate, or some other costly and shining adornments. In any event, the business of the plumber would not be curtailed.

It is admitted that, in the proposed system, the maintenance of a forced draught would usually demand the watchful attention of some human being, and that the outlets from the wash-basins and baths would not automatically cleanse themselves any more than the basins, or than any other domestic utensil. But, if the system possesses all the advantages here claimed for it, the small amount of care and labor required to insure its operation and to keep the parts clean, is a small price to pay for exemption from the formidable and protean evils of modern plumbing. In order to insure the successful operation of this plan, it is essential that the flow of air shall always be maintained in the proper direction, and that the means taken to secure this result be simple, inexpensive, durable and always under the control of the occupants. As upon this

the success of the plan mainly depends, it is the special object of this paper to prove to sanitary engineers that this is practicable and easily attainable.

The forced upward draught in the house vent may be secured by any one of the following means, viz.:

A.—In houses where there is a chimney flue in which a fire is constantly maintained day and night,—as in hotels, flat buildings, factories, etc., the vent is run up in contact with the heated masonry of the flue.

B.—A gas jet may be inserted in the vent at any point of its course and kept constantly burning.

C.—In houses where steam or hot water is constantly used, a short section of the vent-pipe may be kept hot by passing a few coils of steam or hot-water pipe around the vent and in close contact with it.

D.—Where hot air is constantly used for drying or heating purposes, a section of the vent-pipe may be boxed in so that a current of heated air shall pass around it.

E.—A small chamber may be built around the trap and lower end of the vent-pipe, in which chamber air may be kept heated by a small base burner stove, in which fire is constantly maintained.

F.—Where steam, electric or water-power is constantly employed, the draught may be maintained by means of a fan or an air-pump of any kind which may act, either by suction or by injecting the air into the lower part of the pipe.

G.—In buildings ventilated by the vacuum movement, either mechanically or by an aspirating chimney, the vent-pipe should be carried directly into the ventilating flue. Where the mechanical movement is used, a small branch may be led from the force main supplying an upward air jet in the vent-pipe at any point in its course.

Plan *A* should never be solely relied upon, because any chimney is liable to be out of use occasionally, owing to accident or for the purpose of repairing the furnace or machinery. Where the chimney is used, it should only be as an adjunct to some one or more of the other means indicated. In fact it is safer not to rely on any one means. At least two should be used in conjunction, so that should one fail the other may be available. In dwellings especially, the kitchen chimney as a sole means is unreliable and is becoming more so; for the time is not far distant when gas will replace solid fuel for cooking and other domestic uses.

It is well to call attention to one result of the omission of local traps which, at first sight, might be considered a serious defect in the system. When a fixture in the upper part of a house is emptied, the sudden rush of water in the upper part of the pipe may tend to force more or less air out of the openings in the lower fixtures. In the case of wash-basins and baths this may be effectually prevented to any objectionable degree by throttling the outlet so that the plug has less area than the waste-pipe. The same plan should be used for water-closets, the branch should be of 3-inch pipe discharging into a 4-inch soil-pipe. Two and a half inches is shown in practice to be large enough for the branch; hoppers with that size discharge being successfully used in insane asylums.

DISCUSSION.

CHARLES B. BRUSH, Director Am. Soc. C. E.—It seems to me that the plan recommended by the author is open to criticism. The worst gases that we have to contend with are those which generate in the houses rather than those from the sewer. The sketch marked Fig. 3 seems to indicate that, in the writer's judgment, a trap should be maintained on the sewer at the entrance of the building. It is proposed to protect this trap with two shafts, running above the roof in front of each building. There is no other provision made for ventilation of the sewer pipe, and no other traps are permitted. No other provision has been made for carrying off the gases from closets and sinks. The sketch, Fig. 1, provides for traps and for their ventilation. The fresh air intake is at the entrance of the building. The other sketch seems to be the same as the "present system," with the exception that the fresh air flue runs up to the top of the house. I doubt very much the necessity or the desirability of this trap at the entrance of the house. I think it is better to allow complete circulation to take place, by providing a fresh air vent to the roof from each trap. The criticism of the author in relation to the fresh air intake is good. The better way to avoid complications is to abolish the trap in front of the house. This trap is always filled more or less with grease and the deposits which come through the pipes. Finally the trap chokes and then there is no escape for the gases except into the houses.

The author criticises what he calls the "present system," because it is not automatic. From time to time this system will have to receive attention. So will any system. The principal attention this one will have to receive is simply to see that the basins are used. The water will have to be turned on, and as soon as this is done the trap will be filled. I cannot imagine any attention that can be more readily given. Every

intelligent householder ought to know that the water in each trap should be renewed at least once in every two weeks. If there are air vents from the traps it will be almost impossible to empty them and thus break the seal. The basins ordinarily in the living rooms of the houses, the kitchen, etc., are used so constantly that there is no question about these traps. The question arises principally in relation to the guest chambers, and to the house after it has been closed awhile. Common prudence would teach that under these circumstances it is better to turn on the water and let it run for a time before using rooms that have not been occupied for some time. I think it is dangerous to rely on any system such as is proposed in Fig. 3 of this paper.

Latham Anderson, M. Am. Soc. C. E.—It seems to the author that Mr. Brush has failed to understand fully the essential points of difference between the present system and the one proposed. The essential features of the latter are: 1st, the complete isolation of the air in house plumbing from that in the sewers—thus constituting in effect two distinct systems of ventilation; and, 2d, the most efficient ventilation of each system by the simplest practicable means. Now, a trap of some form is the only means yet devised of separating the two systems, as far as the author is at present informed. The use of a cut-off trap between the sewer and the house, with an external vent from the sewer extending above the roof, is not a novelty. It is a feature demanded by many of the most advanced sanitarians of to-day. The use of the external trap, either with or without a sewer vent, is almost universal. Therefore, all of Mr. Brush's arguments against the use of this trap apply as well to the existing system as to that proposed by the author.

Mr. Brush says, "It is proposed to protect this trap by two shafts, running above the roof in front of the building. There is no provision made for ventilation of the sewer pipe, and no other traps are permitted. No other provision has been made for carrying off the gases from closets or sinks."

The statement that both vent pipes are designed to "protect" the main trap evinces a misconception of the author's design. The inner vent pipe is not intended in any sense as a protection to the said trap, but only as a means of ventilating the house system. As to there being "no other provision made for ventilating the sewer pipe"—what existing system has as much? Surely Mr. Brush could not have read that part of the argument showing the excess of area of the vent pipes over that of the sewers themselves, in all sewers of 18 inches diameter and less.

The statement that "No other provision has been made for carrying off the gases from closets or sinks," implies that, i Mr. Brush's opinion, this means is inadequate. Fortunately it is not necessary to discuss this on abstract principles, as an untried experiment. Scharn Weber's patent of a gas jet burning in a vent pipe has proved a complete

success in maintaining a constant circulation and an entire absence of odor about the fixtures. Urinals attached to the Smede-Ruttan system of heating and ventilation are notably well ventilated and free from odor. In the Ortiz flat building, in Cincinnati, a forced upward current is maintained in the vents by having the lower ends of the latter open into the cellar and carrying a single return of steam heating pipe a few feet up the vent shaft. Neither is the downward draught in the local vents any longer a matter of experiment. Mr. Murphy has demonstrated its practicability and its benefit in the last-named city, by applying it in practice. Carrying the air currents through the soil and waste pipes in the same direction as the liquid flow, is the distinctive feature of Murphy's system. This fact seems to be entirely lost sight of by Mr. Brush when he says, "The other sketch (Murphy system) seems to be the same as the 'present system,' with the exception that the fresh air flue runs up to the top of the house."

Referring again to the main trap, it is said, "This trap is always filled more or less with grease and deposits which come through the pipes. Finally the trap chokes and then there is no escape for the gases, except into the houses." Do not the same objections hold with regard to all the other traps in the house ? And is not a small trap under a low scouring head more apt to clog up than a 4-inch or 6-inch trap under the high fall usually obtaining at the main trap? As to obstruction by grease, it is the author's experience that straight pipes anywhere below the kitchen or butler's sink are more apt to become plugged by grease than are the traps. The presence of kitchen grease in either is inexcusable, since a good grease trap so completely prevents it. A properly designed trap should be so located (preferably within the house) as to be readily accessible, and should have a hand-hole for cleaning out obstructions.

The author's criticism as to the non-automatic character of the present system is also misunderstood. It is meant that householders generally seem to regard it as automatic, when reality it is not. The author agrees with Mr. Brush that every system requires attention, the one proposed not being claimed as automatic. That system is the best which is simplest and has the fewest points requiring attention. In the proposed system there are three, viz.: the main trap, the grease trap, and the appliance for producing a forced draught. Furthermore, the occupant of the house will be compelled to attend to the first two of these appliances, for if he do not, the system will not work at all. As far as the main and grease traps are concerned, this is true of any system of plumbing; so that the ventilating apparatus is the only feature to be looked after, and, where constant steam service is used, this becomes automatic, as at the Ortiz flats, above noted. Mr. Brush adds: "If there are air vents from the traps it will be almost impossible to empty them and thus break the seal." The author must take issue with this statement.

Exhaustive experiments made by Dr. Fergus, of Scotland, upon vented traps conforming in every respect to existing sanitary laws showed that they are not an efficient safeguard against the siphoning or forcing of traps.

Quoting again from the "discussion":

"The question arises principally in relation to the guest chambers, and to the house after it has been closed a while. Common prudence would teach that under these circumstances it is better to turn on the water and let it run for a time before using rooms that have not been occupied for some time."

If in any occupied house or room the traps become unsealed by evaporation, it is common experience that the house suction makes the house the main vent for the sewers of the neighborhood. If this sewer air should contain any noxious germs, the carpets, hangings, bedding—even clothing packed in drawers and trunks, becomes saturated with the vitiated air. Under these circumstances, if the Niagara River were emptied through the traps, it does not appear that the above named textile fabrics would be disinfected thereby.

Finally, the following sweeping conclusion is arrived at: "I think it is dangerous to rely on any system such as is proposed." But the dangers are not specified. Is it the danger of the entrance of sewer air into the house? That is obviated by destroying all back pressure from the sewer by the numerous house vents, as explained in the paper, and by back pressure valve. Where a house is to remain unoccupied for some time the breaking of the seal could still further be guarded against by covering the water in both branches with a layer of glycerine. This would retard the evaporation of the water for months.

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THE PROPOSED LAKE ERIE AND OHIO RIVER SHIP CANAL.

By John M. Goodwin, M. Am. Soc. C. E.*

WITH DISCUSSION.

The General Assembly of Pennsylvania at its session of 1889 authorized the appointment of a commission to "determine the feasibility of connecting the waters of Lake Erie and the Ohio River by a ship canal;" and, in event of finding such a connection feasible, "to lay out a route for such canal," and make an estimate of the cost of construction of the waterway. The commission on this subject, appointed by Governor Beaver in accordance with the terms of the joint resolution above quoted, entered upon the duties with which it was charged in the spring of 1890, and in February, 1891, rendered to the Legislature a report declaring the construction of a proper ship canal, to afford navigation for large vessels between Lake Erie and Pittsburgh Harbor, to be entirely feasible; and estimating the cost of such canal (with locks 300 x 45 feet in the clear, with 15 feet of water on the miter sills), at $27 000 000. The commission printed an edition of five hundred copies of its report; and upon filing said report, placed in the hands of the State Printer photo-

* This paper was given in outline by Mr. Goodwin, who was a member of the commission, at the Convention held at Lookout Mountain. Mr. Goodwin died October 27th, and he had not read the final proof of the paper.

engraved plates of the profile of the canal route, and of nine maps and one lock diagram prepared by the commission for illustration of its work.

Upon receipt of this report the Legislature adopted a resolution directing the printing, by the State, of three thousand copies of the report and the accompanying maps, for use of the commission. At the suggestion of the commission, it further instructed the representatives of Pennsylvania in Congress to take steps to secure a review of the work and findings of the commission, by officers of the U. S. Engineer Corps; and directed the commission to submit to the Legislature a supplementary report to be made after the rendition by such engineer-officers of their report upon the review sought, as aforesaid.

In February of this year the commission placed in the library of this Society a copy of its report, rendered as above noted; and now presents for the inspection by the convention several maps, printed from the plates aforesaid,* showing, respectively, the country between Lake Erie and Pittsburgh, with the projected route of the ship canal, and the location of the canal through each of several of the larger manufacturing towns of the Shenango Valley. These maps the commission delivers to the Secretary of the Society for deposit in the Society's library.

Circumstances do not favor the presentation at this time of any extended remarks upon the ship canal project in question; nor, indeed, were ample opportunity offered, could the author do more than review the matter in this regard presented by the report of the commission, which quite exhaustively treats its subject—considered with relation to the engineering features of the enterprise and to the circumstances in view of which the commission adjudges the Lake Erie and Ohio River Ship Canal a commercial necessity.

The commission claims that the report fully demonstrates the feasi-

* List of maps prepared by the Canal Commission. 1. General map of country between Lake Erie and the Ohio River, from the Allegheny River on the east to longitude of Ashtabula Harbor on the west, with route of canal, etc. 2. Map of Conneaut Harbor. 3. Map showing location of ship canal through Greenville, Pa. 4. Map showing location of ship canal through Sharpsville, Pa. 5. Map showing location of ship canal through Sharon, Pa. 6. Map showing location of ship canal through Newcastle, Pa. 7. Map showing location of ship canal through Rochester, Pa. 8. Sketch of route of canal in vicinity of Conneaut Aqueduct. 9. Map of right bank of Ohio River, from Davis Island Dam to Rochester. 10. Diagram illustrating plan for passing vessels from ship canal through Davis Island Lock into the Ohio River. 11. Profile of canal route, from Conneaut Harbor to the Ohio River.

Maps not prepared by the commission: *A*. Map of the Monongahela River. *B*. Map of country between Pittsburgh and Lake Erie, 1824.

bility of constructing the canal, and clearly illustrates the manner in which and the extent to which, the canal will facilitate and cheapen transportation between the ore, grain, and lumber-producing Northwest and the iron-making and coal-producing regions of Eastern Ohio, the upper Ohio Valley and Western Pennsylvania. It presents, likewise, thoroughly authenticated facts fully supporting the finding of the commission that the construction of the ship canal in question is the only means available for that enlargement and betterment of existing transportation facilities between Lake Erie ports and the iron-making districts of Eastern Ohio and Western Pennsylvania, which is absolutely necessary to the maintenance of the present rate of industrial progress of those districts, as well as to the continued development of the mineral resources of the Northwest, and an adequate and otherwise satisfactory supply of the Northwest with fuel.

Of the various considerations presented in the report arguing the propriety of the adoption by the nation of the measure of building the Lake Erie and Ohio River Ship Canal, none are more intrinsically important than those relative to the necessity of the canal as a means for ready defense of our lake ports, and of the great fleets navigating our inland seas by authority of and under what ought to be the sure protection of the United States of America.

With regard to suggestions that the canal will best be constructed so that, if need be hereafter, the available depth of the waterway may be made about two feet greater than that for which the commission has planned, the report says: "The questions raised by this suggestion will, of course, have due consideration by those who, eventually, will determine the course preferably to be pursued in this and other like directions."

The discussion of this question of the appropriate depth for this canal involves the consideration of many and very widely comprehensive fields of inquiry. The author will only say now, that the commission, after duly examining the matter, sees no sufficient ground for modifying its recommendation that the canal be made with a bottom-width of 100 feet and depth (of water) of 15 feet.

The author trusts that he may soon be able to supply copies of the report of the commission, and this will give a complete exhibit of the facts upon which the conclusion is reached that the canal is a "necessity."

To make a very brief statement of the project, it is to carry a canal from Lake Erie, at a point just west of the State line between Ohio and Pennsylvania, to the Ohio River at Davis Island Dam. To bring the canal to the Ohio River merely would be money and time thrown away, because there would be no inducement for vessels to come through if they were landed in the Ohio River without means of getting to the City of Pittsburgh. For that reason the commission decided to continue the canal to Davis Island Dam, and there make the connection. With that connection there would be a depth of water from Lake Erie to the harbor of Pittsburgh. There was a canal which connected Lake Erie with the Ohio River, extending from Erie Harbor to the Ohio River at a point 26 miles below Pittsburgh. In consequence of this termination, so far short of its proper objective point, the canal had very little commercial value and was of very little use. If it had not been for the diverse interests of the railways it might, however, have served a better purpose than it did. The distance from the lake to the Ohio River at the mouth of the Beaver River, by the route of the canal, is 103 miles; it is only a few miles greater than that on an absolute air line. The point where the proposed canal crosses the summit here is 66½ feet lower than the surface of the old canal where it came across the summit. West of the bluff, on the State line facing west, is a plateau which extends north and south a distance of perhaps 15 miles and east and west a distance of 10 miles. The railroads coming from Lake Erie across the country to Pittsburgh have a 60-foot grade coming up from the lake. There is no road going south that has not grades of at least 60 feet to the mile. The Erie and Pittsburgh, which leaves the Lake Shore at Girard, has 62½ feet, and there is no summit level. Neither one of these roads has any summit level, but we have for our canal a summit level of 20 miles in length, and it is only a question of time in operation, whether or not it will be economical to make it more than this. A summit level 30 miles long can be made there if desired.

The question of the feasibility of the scheme as an engineering project we cannot now go into, because of lack of time. We will have to ask you to accept the statement made in the report, of which there is a copy in the library of the Society, that the construction of the canal is perfectly feasible. The principal question to be taken into consideration would be whether or not there is any commercial necessity for the canal. Here is the Mahoning Valley, where there are fifteen furnaces; in the Shenango

Valley there are twenty-three furnaces. In Allegheny County and the Mahoning and Shenango valleys 35 per cent. of all the pig metal produced in the United States is made. The "two valleys" made 1 250 000 tons in 1889, and Pittsburgh about 1 300 000 tons. The point in regard to the commercial necessity is this: if the railroads now carry material for this metal and deliver it to the furnaces along the valleys and at Pittsburgh, why should not they continue to do so? If the increase in the production of pig metal maintains itself at the rate of the last two or three years, in the year 1900 we shall be making between 17 000 000 and 18 000 000 tons of pig metal; and we must bring into this country more than twice as much iron ore as now. This cannot be done by the railroads. If the iron-making districts are to maintain their position the material must be brought to them. These districts have a right to an opportunity to keep up with the advance, but if not provided with additional means of handling their ores it is an impossibility for them to maintain their position. The canal would have a sufficient capacity to carry to these regions all the ore they want. A question that arises in every inquiring mind is, How is it possible that these railroads are so restricted in their ability to deliver freight?

A vessel bringing to a harbor an average cargo of ore carries perhaps 1 500 gross tons. Now, this quantity put into railroad cars will load about seventy-seven cars, occupying about 2 600 feet of track; while in the vessel, that ore occupies a space only about 215 feet long, and that is one of the essential facts to be considered in this matter. The railroads find it impossible to get to the furnaces with such enormously long trains of cars; one end is at the furnace, but the other is half a mile away. It is an impossibilty that the rate of supply to the furnaces by the railways shall be very much increased, because all available grounds are fully occupied by the railways. It is impossible to get a new railway into any one of several of the most important manufacturing towns. For these reasons the capacity of the railways is limited.

(Mr. Goodwin exhibited a map of the ship canal through certain towns, showing how fully the ground is taken up by railroads. This and other maps were donated to the library by him.)

These are the reasons on which we build up the statement that our canal is a commercial necessity. The cities along the lake shore do not appear to take any interest in the matter at all. Cleveland has an idea that the construction of a canal here would have an injurious effect

upon the trade of that port. Ashtabula is the largest ore-port on the lake. Fairport and Ashtabula are simply the lake ports of Pittsburgh and the two valleys; they have no business beyond vessels going to and coming from the ore-regions, so if the iron and coal industries were entirely removed, the business of these two ports would be wiped out. You are aware that Cleveland has an enormous manufacturing industry, as has also Erie. No city in the world turns out the number of stationary engines that Erie does. One concern alone turned out 1 200 stationary engines last year. The business of Cleveland, if the iron and coal industries were wiped out, would be reduced 70 per cent. While it might appear at the first glance to a Cleveland man that the construction of the canal might be injurious to that city, yet precisely the contrary is the fact.

The report of the Commission refers to a map that was printed by the Government about 1824. When this canal project was resurrected the War Department hunted up the plate and printed a lot of copies, of which the one here exhibited is one.

DISCUSSION.

E. P. North, Director Am. Soc. C. E.—Mr. Goodwin spoke about the old canal being abandoned. I would like to ask when it was abandoned, how long it carried freight successfully, the cause of its abandonment and the size of the canal?

Mr. Goodwin (showed on the map the route of the canal).—The canal was 28 feet wide on the bottom, 44 feet on the surface, and had a depth of 4 feet of water—on the old "Erie" prism. The summit cut of the old canal was about 8½ miles long. There was an average cutting of nearly 20 feet; maximum 27 feet. While the summit cutting was in progress the French Creek feeder was also in progress, and before the summit cut was completed the feeder was nearly completed, and a large amount of work done on other portions of the canal besides. The engineers in charge found it impossible to control the quicksand on the summit. There was a certain point to which they could reduce it, but beyond that they could not get it down. You can imagine the feelings of the engineer in charge, our Past-President, Milnor Roberts. Finally all the water available for the summit level and for 61 miles of the canal had to be pumped into the canal with a wheel and big bucket, such as they formerly used in Chicago. That was one reason why the canal was not a commercial success. It never had any depth in it because of the

quicksand. In 1863 or thereabouts the Pennsylvania Railroad, or those interested in it (or perhaps just as much the New York Central as the Pennsylvania Railroad, because the Central people furnished the money for connecting the project), began a railroad to parallel the canal. This road was completed in 1864, and is now operated by the Pennsylvania Company. As soon as the road was completed and in actual service, steps were taken to close the canal. Two bills passed the Pennsylvania Legislature on the same date; the first incorporating the Pennsylvania Company, the second authorizing the Erie Canal Company to sell their canal to any railroad company, in order that the railroad company might use the canal for the construction of railway tracks. There was a clause in the bill to the effect that, providing the railroad company did not use it for railroad purposes, they might use it for anything they wished. The old canal company having become much embarrassed (a large number of judgments having accumulated against it), Mr. Scott made a deal whereby he came into possession of the canal. There were other steps taken authorizing the selling of the canal. The canal was not immediately dilapidated; for several years after the purchase there was a show made of operating it; but it was not suitable for operating on account of the condition I speak of. The canal was then sold out by piecemeal. If it had been continuous to Pittsburgh, I think it would have been in existence still. Local business before that canal was built was nothing; the canal built up a coal export from the Chenango Valley. Until the canal was constructed there was no export of coal from that region. When the canal was built coal export sprung up; the canal made that trade possible and fostered it and was very useful to it; and the coal people would have liked to see the canal continued. When the railroad came in they were forced to give the railroad their trade.

Mr. North.—I desired, Mr. President, to bring out a direct statement in regard to my theory and perhaps the theory of many others—that the canals of this country have passed their usefulness in consequence of the increasing loads that engines can carry and the decreased cost of transportation on the railroads. If you build a canal that will accommodate a boat of 40 tons, you can then make no improvement in the economy of transportation on the canal. The only way in which you can improve it is by lengthening the locks so that you can put two or three boats through, or by destroying the locks and building larger ones. I hope the gentleman will not consider it personal when I say that he proposes to connect a navigation which is now of 16 feet depth and will be almost surely 20 feet within a few years with a 15-foot canal, and do business through it and with the largest iron center in this world. Now the boats already built on the lakes exceed in depth, width, length and capacity the locks which this commission is providing for them. As soon as the new Sault canal is built the size of the boats will be

increased; two or three years after the present lock, which has been called the new lock, at the "Soo," was built, only 11 per cent. of the vessels passing through that lock could have gone through the old locks. There will be a very decided change; they will begin to cheapen their rates on the lakes and necessitate the railroads decreasing their freight rates correspondingly. There is a tendency on the part of American engineers, when extending a waterway, to make it smaller than that which they connect with. This canal has 15 feet on the mitre sills.

In Germany an improvement was made in the Main below Frankfort, where there are 350 miles of navigation. They made locks on this improvement, with a depth of 7.3 feet, when the available depth in the Rhine is only 6 feet. If that course had been followed here he would have made his canal some 22 to 23 feet; that would have allowed the vessels passing through the St. Clair flats to maintain a fair rate of speed in the canal. The capacity of the vessel is said to vary with the cube of the depth of its channel. The cube of 14 feet is 2 744, and the cube of 20 is 8 000; that is to say, there is some three times greater capacity through increase of depth with corresponding increase of width. Wherever larger expenditures have been made for the improvement of waterways, the result has been an increase in traffic and decrease in the expense of conducting it.

In German waterways—and Germany could be put down in Texas and leave a wide fringe of land outside of it—the increased ton mileage on the waterways has been 66 per cent., and at the same time without any increase in the length of railroads the increase of ton mileage on them has been 52 per cent. One of the engineers of the German waterways says it is certainly without a parallel in history that a means of communication which has existed for centuries should double its traffic in ten years. The doubling of the traffic was made by improving the waterways, by increasing the depth of the locks, and increasing the navigable depth.

Mr. Goodwin.—In regard to the relative cost of transportation on the lake and by rail, the furnaces in Pittsburgh paid two cents a ton more on iron ore from Ashtabula to Pittsburgh (145 miles) than they paid on the same ore for a distance of 650 miles on the lakes.

If the report of the Canal Commission makes a statement it backs it up with figures. You can ascertain with very little trouble precisely the cost of doing any kind of work. The canal will be, if it is ever built by the United States Government, an absolutely free canal. A vessel of the "canal" class will carry between two and three thousand tons, and we have some that will carry more. The fact is, a vessel of that class can make a great deal more money by loading about a foot less than they do. They can make about 33 per cent. more money than under the present practice. In 1873 there was a craze on the lakes that was similar to the

narrow gauge craze, the idea that the only thing necessary was that they should build four or five barges and let a steamer tow the barges. I told them: "Let the barges go by themselves and the steamer go by itself; they would earn a great deal more money in the season than they could running together;" and that idea they hooted at.

As I said, this canal, if built, will be a free canal. Formerly the canal toll on grain from Buffalo to Albany was six cents per bushel; they reduced it to three cents; that was found to be too much. They saw it must be a free canal, or New York would lose its supremacy as a grain port. The people of the outside counties of the State of New York protested very seriously. Chautauqua County contended that it was not fair to tax a poor county like that \$5 000 or \$6 000 per year for the support of the Erie Canal. Kings County and the County of New York (being the City of New York) said to Chautauqua County: We are asked annually to pay \$25 000 school money to Chautauqua County, and Chautauqua County is asked to pay \$5 000 only for the support of the canal.

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ON THE STRAITS OF JUAN DE FUCA, PUGET SOUND; AND GOVERNMENT IMPROVEMENTS ON THE PACIFIC COAST.

By BOLTON W. DE COURCY, M. Am. Soc. C. E.

WITH DISCUSSION.

In the year A. D. 1592 (according to the "Encyclopedia Britannica"), an old Greek pilot, in the service of Spain, discovered the straits of Juan de Fuca, so called after him. The "Chambers' Encyclopedia" makes a claim that it was visited by Captain Cook in the year 1778, but Kipps's "Narrative of the Voyages Round the World, Performed by Captain James Cook," shows that it was Nootka Sound, on the west coast of Vancouver's Island, that he visited. So we shall insist that "the old Greek pilot" has the honor of discovering one of the most wonderful inland seas on the surface of the globe, especially when its phenomena are taken into consideration.

With an average width of about 18 miles, from Cape Flattery to the Race Rocks, a little to the east of north from Port Angeles, the straits expand to the north to a width of 20 miles at Victoria, B. C., there dividing into several passages, the Haro Strait, the Middle Channel and Rosario Straits, to the south-east of which is Admiralty Inlet, the entrance to Puget Sound. The shores generally are bluffs, covered with a dense growth of red and yellow firs, with cedars and hemlock, and

are so bold that vessels can approach them to less than a cable's length, in almost every place, and the depth is wonderful—in many places exceeding 100 fathoms.

Spits are found of various sizes at nearly every headland where there is any change in the general alignment of the shore, causing a sudden alteration of the tide-flow. At Port Angeles is one of the most extensive; here the original bluff took a sudden bend to the south-east, and the resultant is a spit about 4 miles long and from $\frac{1}{8}$ to $\frac{3}{8}$ of a mile wide, with a shore so bluff on the harbor side, that the light-house tender can run alongside and make a landing with a gang-plank. On the other side of the spit the beach is more shelving. This spit encloses a most beautiful harbor, about 2 miles wide.

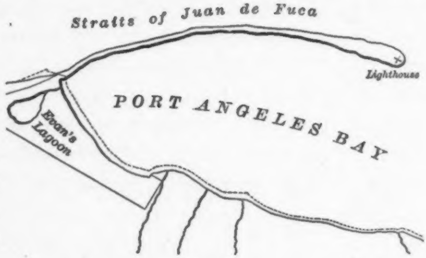


FIG. 1.

There is a total absence of any river or stream of navigable size, discharging into the straits; the Elwha, a mountain stream which has cut its way through a gorge, making a deep and narrow cañon, is the largest. There are, however, many beautiful streams flowing from the Olympic Mountains, furnishing the purest water and well stocked with speckled beauties.

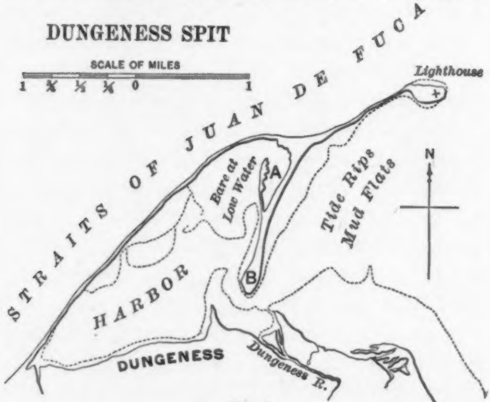


FIG. 2.

Twelve miles from Port Angeles spit are the curious spits of Dungeness. See Fig. 2. The Dungeness River rises in the Olympic range, and, as is seen in the present state of the harbor, brings from the foothills a great deal of silt. The interest here is concentrated on the question: In what succession were these spits formed?

The people cut a small channel through at the west end, expecting that it would create current enough to erode the mud flats and save the destruction of the harbor, but it had no duration, showing the same agents to be at work that first made the formation. Speculating, the author would suggest that the inner spit at *A* was caused by an eddy, while that at *B* was formed by the discharge of the river in combination with the ebb tide, the main portion being made by eddy. Southeast of this is Sequim Bay, at the head of which is another somewhat similar spit.

FIG. 3.

An examination of the chart, a small portion of which is given in Fig. 3, shows still further to the east a small bay at the south end of Port Townsend Bay or Harbor. At its south end, between the

waters of Oak Bay and Townsend, is what is called the Portage (from the circumstance of the Indians choosing this route to reach the upper sound, carrying their canoes over this narrow bar instead of the continuous water route around Marrowstone point). Through this small bay and bar, the people asked the Government to make an appropriation for a ship canal, claiming that it would shorten the distance to Seattle, Tacoma and other places on the upper sound, and enable the small stern-wheelers to reach Port Townsend in the winter, at which time they cannot be insured while rounding Marrowstone Point. This bar is evidently formed by the meeting of the tides in Oak Bay and Port Townsend, and if the canal were dredged the same agents would fill it again. The engineer to whom it was referred reported rightly aga nst the scheme. East of Port Townsend Bay is Scow Bay, which also was once connected with Oak Bay and is yet, by a small channel which the littoral drift is continually working to close, and will, eventually, when the elongation of the channel reaches the Portage at the head of Oak Bay.

The "tide rips" are the most curious phenomena of the straits, Puget Sound and other waters of this system. A reference to a map will show that Puget Sound is formed of a number of long, narrow gulfs, connected with narrow passages lying principally in a northerly and southerly direction. The depth of these gulfs is wonderful, reaching 150 fathoms in places, and seldom, except at the heads, falling below 20. There are two tides daily, of different heights, and affording a "long and a short run out." The sound is 125 miles long and from 5 to 25 miles wide, with a coast line of over 800 miles in extent. The rise of the tide reaches from about an average of 10 feet at Port Townsend to 18 at Olympia, at the head of Budd's Inlet. All the water to supply this rise has to pass through Deception Pass, which is about 300 or 400 feet wide, and between Point Wilson and Admiralty Head, which are distant about 5 miles from each other.

In many places vast eddies and whirls will at times be seen on passing in a steamer, and while the water around the steamer is quite calm, and seems as though covered with oil, it will suddenly develop into a succession of short waves of wonderful height, and continue in this state for a time, when it will as suddenly calm down. These tide rips are caused by rocks and inequalities in the bottom over which the tide ebbs and flows with a rapid current. They occur often in great depths and are extremely dangerous to small boats.

Mr. Freeman's remark, in the discussion of his interesting paper on "Hydraulics of Fire Streams," is here in point. Referring to the effect of the small inequalities of the interior surface of the hose, he says: "As to the means by which such small roughnesses of surfaces are able to induce such powerful effects upon the friction loss, may we not consider that, instead of being due mainly to friction of the water upon the pipe, they are most likely due to the ability of these small projections to set the whole stream to its very center into a condition of turmoil and minute eddies, just as a single stone on the bottom of a smooth and deep canal is sometimes seen to produce a 'boiling' at the upper surface."

The shores of the straits and of Puget Sound are from 300 to 800 feet in height above the sea; and, as in the straits, Puget Sound has no rivers of importance or size flowing into it north and east of the City of Seattle. The beauty of the scenery of the sound requires more eloquence to describe than the writer possesses ; suffice it to say, the eye never tires when viewing it, and with the perpetual snow-covered extinct volcanoes, Mounts Baker and Rainier, sublimity as well as beauty is not wanting. Adjoining the sound are three lakes, Union, Washington and Samamish. A board of the Corps of Engineers of the U. S. A. is now devising a project for connecting these lakes with the sound by a ship canal. The difference of heights to be overcome, exclusive of the rise of tide, is only 12 feet, and the lakes being fresh water, will give the City of Seattle one of the finest fresh-water harbors in the world. The connection of all three will require a length of only 12 miles, and as the teredo is very destructive in the sound, Seattle will have an advantage over every other city thereon, as the fresh water acts as a cleanser of barnacles and all other *balani* that foul the bottoms of sea-going craft.

At Olympia, the State Capital, which city is situated at the head of Budd's Inlet, a project is prepared for the improvement of the harbor. Here, a stream called the Tum water enters the head of the inlet and has filled it up for quite a distance with silt. The project provides parallel bulkheads or training walls 400 feet apart, with a dredged channel 260 feet wide on the bottom; the excavation to be deposited or pumped back of the bulkheads, which are formed of two rows of piles, each with caps, stringers, breast-timbers, sheet-piling, and some fascines held in position with stone. The project calls for an appropriation of nearly $300 000. It is intended to furnish a channel 12 feet deep at lower low water, to be widened to 400 feet for 1 500 feet next to the city, and to keep the Tum water from flowing into it.

Strange to say, there is not one large, navigable river rising in the Olympic Range. The Soltuck, Colower and Beaver form the Quillayoute, which for some 10 miles from its mouth is navigable, but cannot be entered, from its bars; its embouchure is in the Pacific, some 40 miles south of Cape Flattery. The first harbor south of Flattery is Grays; it is called after Captain Gray, commander of the ship *Columbia,* who explored the river of that name (called so by him after his vessel), in the year 1792. Several small streams enter into this harbor, besides one of considerable size, the Chehalis; this is navigable by small steamers for some 25 miles from where it enters the harbor at Aberdeen, and for those that draw 15 feet at high tide, as far as Montesano, 15 miles. The United States Engineer in charge is now devising and estimating a project, to give 15 feet at all stages of the tide, as far as Montesano. The Chehalis River is formed by the Newaukum and several others, that rise in the foot-hills of Mount Rainier; as far as Montesano it flows through a hilly country; there it becomes tidal, flowing through flats covered for the most part with a growth of spruce, fir and other small timber. These flats have many sloughs taking off from the river, and in some cases entering again some distance off. There are several shoals, between Montesano and Aberdeen, which it is projected to remove; it is also proposed to dike the sloughs, in order to concentrate the water of the river. About a mile and a half from the mouth, the area is 25 300 square feet. The mean radius is 21.88 feet, and the wetted perimeter 1 156 feet.

Gray's Harbor (see Fig. 4) is about 15 miles east and west, of a somewhat triangular shape, and about 12 miles wide in the broadest part. It is a vast extent of mud flats, with a north, south, and middle channel, for the passage of the waters of the Chehalis and tributaries. At the mouth of the harbor, or rather 3 miles past, in the Pacific, is a bar of sand and breakers. The charts of the United States Coast Survey show a minimum depth at low water of $1\frac{3}{4}$ fathoms, when sounded by them. There is evidence that at other times, at low water, 22 feet depth has been found; the probability is that under the forces of nature, the bar crest varies, and at one time or another the water is worse or better for the passage of vessels, as the resultant depth is affected by storms and littoral drift, or the increased waters of the Chehalis in freshets. One of the duties of the United States Engineer in charge is to devise a project for this harbor improvement.

The sketch shows, that on the north shore, commencing at the mouth of the Chehalis River, is situated Aberdeen, a town of about 2 000 population; about a mile and a half west is Hoquiam, say 1 000 inhabitants, and about 2 or 3 miles farther west is Gray's Harbor, about 700 or 800. While all their interests are the same, the real estate agent has antagonized them, and each wants to be the metropolis of the region. On the south side are South Aberdeen, West Aberdeen, say 200 population; Drummond, a town in embryo, one or two others in the same condition as you travel west; then South Arbor, 25 population; Markam, same population, and lastly, on South Bay, Ocosta, a new town, with probably 700 or 800 population, and the terminus of the Northern Pacific

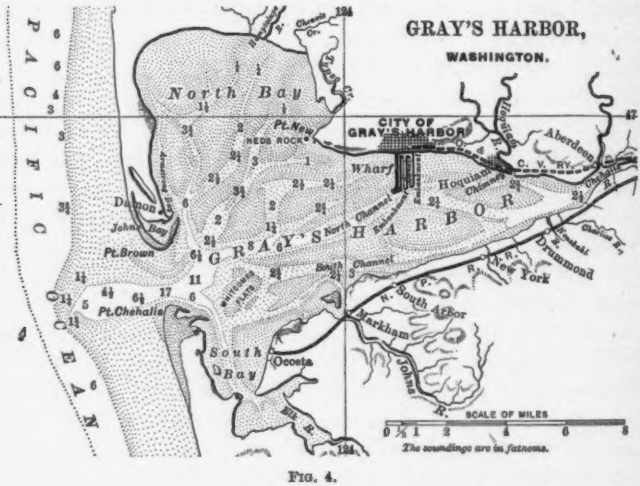


Fig. 4.

Railroad. Thus, the problem is to endeavor to satisfy all these interests; one calling for the improvement of the North Channel, the next for the middle, and the last for the South Channel to be made the main and permanent improvement. The channels are marked on the sketch. There are several shoals in these channels which heavily loaded seagoing vessels can only pass at certain states of the tide, while the main portions are deep enough for any vessels at all stages. There are vast quantities of lumber shipped, and the improvement of the channels, as well as at the bar, is called for and recommended; but the question is, what is the best project? It is proposed to endeavor to train the

principal part of the waters of the Chehalis into the north channel by spur dikes, so as not to close either of the other channels.

The shoals are marked on the plat, or sketch (reduced from the Coast Survey chart), by crosses, all the white spaces being mud flats, bare at low water. The tributary streams are on the north; the Hoquiam,

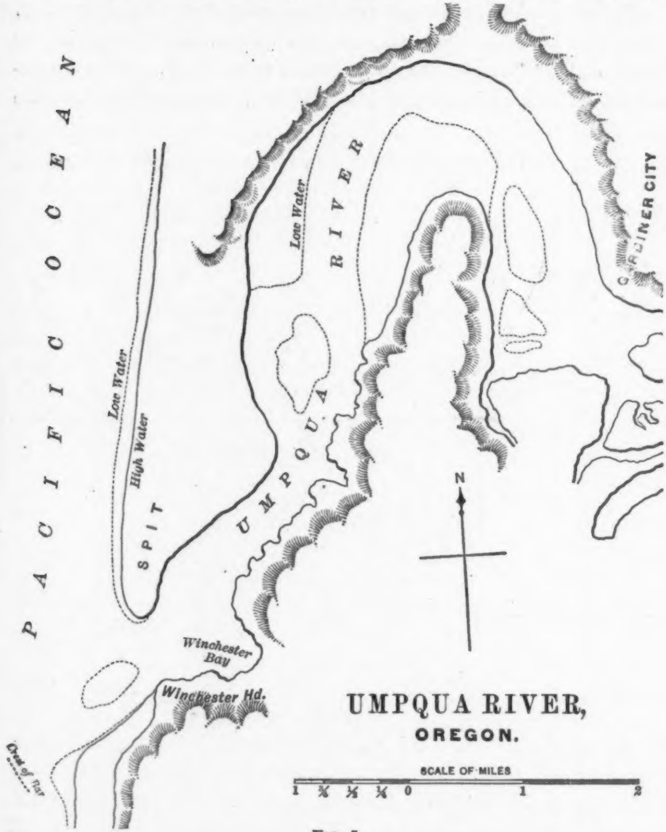


Fig. 5.

a fair stream, deep and navigable, being tidal for 10 or 15 miles, the Typso, Chenois and Humtuluips, with no channels over the mud flats; on the south the Charles, Neus Kah, Johns and Elk Rivers; the Johns being the only navigable stream, and that for 3 miles from its mouth.

Would not the best plan for improvement be to train the Chehalis through either the north or middle channel, so as to concentrate its entire waters, preferably the middle, leaving the flats on each side to be built over and improved in the future; also, to train the Hoquiam to a connection, acting the same way in the case of the Johns?

The next project on the coast is the improvement of Shoal Water Bay. This bay is about 20 miles south of Gray's Harbor; the Northern Pacific is making a terminus on the coast, also at South Bend. There are several tidal streams discharging into this bay; those navigable are the

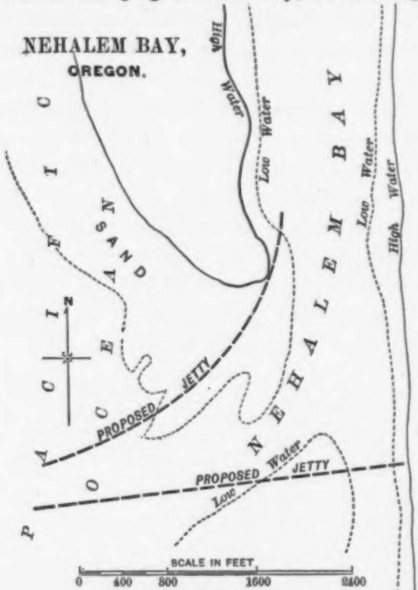


Fig. 6.

North, the Willapah and Nasel Rivers; these are all put forward for projects of improvement. The Northern Pacific is building from its station Chehalis to South Bend on Willapah Harbor. The Shoal Water Bay reaches to within about 5 miles of the Columbia River, at the mouth of which river Major Handbury, of the Corps of Engineers, has successfully built a jetty which has deepened the water on the bar, so as to enable the largest ocean vessels to enter the river with ease and safety. South of the Columbia the following rivers and bays have had either prospec-

tive projects, or projects approved, with regard to their improvement: The Nehalem, Tillamook, Yaquina, Siuslaw, Umpqua, Coos and Coquille.

The prevailing storm winds on this coast are the northwest and southwest. The waves are long and rolling, having a great distance of fetch, though this is affected to some extent by the bars at the entrances. The littoral drift seems to be in preponderance from the north. There are large masses of sand, in most cases, along the shore, which have a cycle of movement. Blown by the wind into the channel, they are carried by the freshets and ebb-tides out to sea, then by the littoral current or the storms are carried on to the banks to be blown again into the channel. It would seem as if an opening in the direction of either of the storm winds should be avoided, and on account of the long rolling waves of the Pacific a straight and parallel arrangement of jetties should be avoided, and an expanding embouchure from the gorge of the jetties for a short distance; but above all things, a diverging trace of the jetties as they enter the harbor, river or bay, as the case may be, except, perhaps, such rivers as have but a small tidal area.

The littoral drift should be made a special study. In several of the sketches herewith, the northern littoral drift can be easily seen; for instance, the Umpqua River shows it plainly at its mouth; Nehalem Bay also, and the Coquille, to a moderate extent.

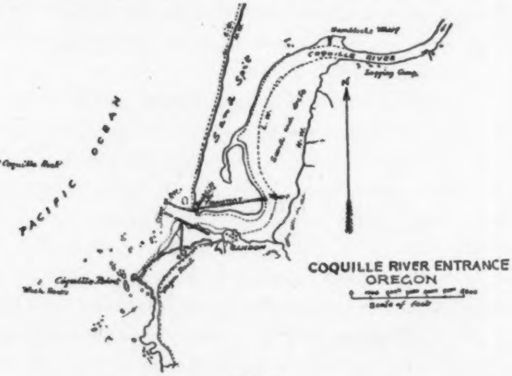


FIG. 7.

In the matter of the sands carried by the wind into the bays or rivers, it would appear that the proper remedy to apply is cultivation of such grasses and trees as can be made to grow under such circum-

stances. Rev. W. L. Rham, in "Flemish Husbandry," describes the improvement of poor white sand. Trenching and leveling is the first operation, then the sowing of broom. In three years, he states, the land can be used to raise buckwheat, and from that on, by the aid of manure, it becomes quite fair land for raising rye, potatoes and some other crops.

The "London Penny Magazine," March 30th, 1844, gives an interesting article on "Plantations on Drifting Sands." After describing the effects of these seaside shifting sands in Suffolk, Norfolk, parts of Ireland, etc., it describes, from the "Quarterly Journal of Agriculture," the successful process used there in the case of the sands of the outer Hebrides: "Square pieces of turf cut from solid sward are laid upon the drifting surface at stated intervals apart, being nearer together on steep places and farther apart in places of less declivity, etc. These turfs prevent the sand from drifting even in the intervals between them.

"Mr. McLeod, of the Island of Harris, adopting another method, has brought into permanent, useful pasture a number of acres of useless drifting sand. He cut the plants of the *arundo arenaria*, or bent grass, about 2 inches below the surface of the ground with a sharp spade; these are carried to the drifting sand and planted in a hole 8 to 10 inches deep; and a handful is put in each of these holes, which are about 1 foot apart. Neither wind, rain or frost destroys this grass; it is excellent for wintering cattle on, and in three years white or red clover will grow amongst it, provided it is well secured."

The pinaster or cluster-pine has been used with great success for fixing sands that drift. This was adopted in France in 1789 as a preventive of drift. In the Gulf of Gascony there are 300 square miles, which, before the attempt to fix the sands was made, could be only compared to a drifting, wavy, white sea. M. Bremontier began in 1789 the almost hopeless task of reclaiming this tract in the following manner: He caused seeds of the common broom to be sown in a direction at right angles to that of the wind, commencing at the seaside; protecting each zone with a line of hurdles, each zone also protecting the next. With the broom-seed he mixed the pinaster in the proportion of 4 to 5 pounds of broom to 1 to 2 of pinaster, immediately covering it with pine branches brought from the nearest woods. These were laid in a shingling manner, and in exposed places, small trunks of trees were overlaid. In six weeks to two months the broom-seeds had grown 6 inches; the

pinasters the first year grew about 3 inches, and in about seven or eight years overtopped the broom. In 1811, a commission appointed by the French Government reported 12 500 acres covered with thriving plantations. These plantations, called pegnadas, constitute the principle riches of the inhabitants, who are almost entirely supported by the preparation of tar and resin from the pinaster trees, raised in what were formerly useless, drifting sand dunes. Nearly the entire tract is now under cultivation.

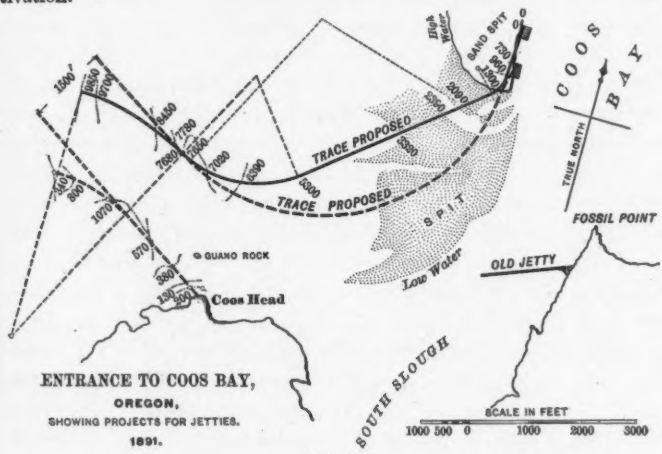


FIG. 8.

One of the most interesting bays on the Pacific coast is Coos Bay. A project for its improvement was approved in 1879, "to construct at an estimated cost of $600 000, a jetty of wood or stone, as may be found best, from a point 250 yards below the northern extremity of Fossil Point, on a line toward the east end of Coos Head, this line in plan curving, so as to be directed at its outer end to the head, or a little to the north of it." Since that time a board of officers of the Corps of Engineers have recommended a new project; they recommend "that the old jetty be not further extended, but that two jetties be built, one from Coos Head, and one from the southern end of the north spit, out toward the bar, ending at a distance apart of about 1 500 feet." The question is, What is the best trace for the jetties? The more southern or curved, convex-toward-the-river plan has been finally adopted. There is a large appropriation for this work. The work will be done

directly by the Government, experience proving that it is more economical than the contract system.

Yaquina Bay has another good appropriation. There are two jetties projected at the mouth of the bay. The project approved is, to

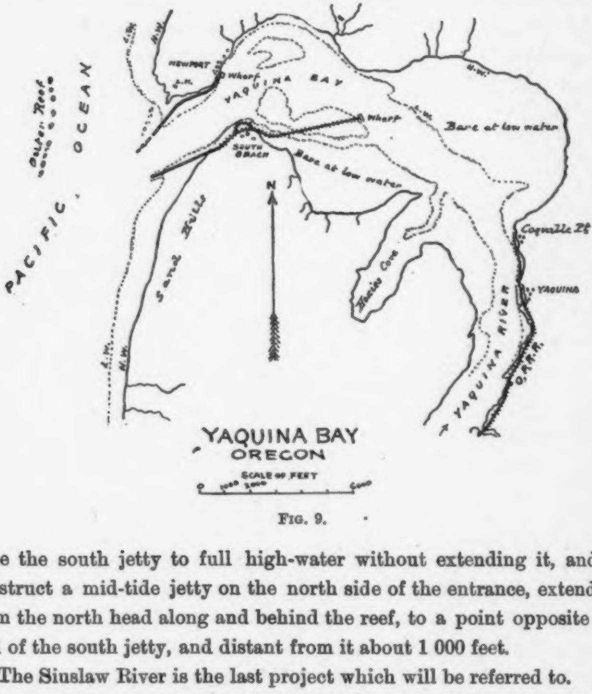


FIG. 9.

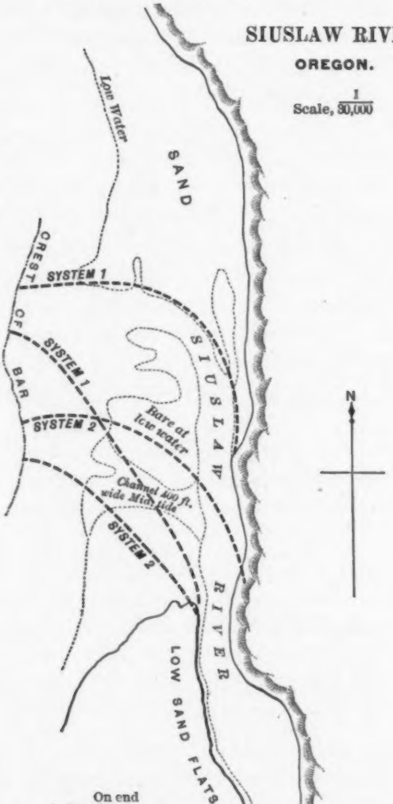
raise the south jetty to full high-water without extending it, and to construct a mid-tide jetty on the north side of the entrance, extending from the north head along and behind the reef, to a point opposite the end of the south jetty, and distant from it about 1 000 feet.

The Siuslaw River is the last project which will be referred to.

An examination of the preliminary sketch (Fig. 10) shows a peculiar course to the river, a large bend to the west along the south end of a sand bank which is washed out by the stream, following the concave side of the bend. There is, of course, a tendency to wash or erode into this sand to the north. Coming up from the south is a sand spit, with an incipient channel forming as shown. In devising a project, is it better to take the new channel and foster it with the system of jetties as shown, or take the river as now, confine it with the north jetty and afford a larger tidal area, that of the river not being of large amount? The estimates of the cost of construction do not differ enough to make the choice of

one of them be governed by the expense of the construction being a minimum.

The main object should be in all such improvements to obtain and maintain a good bar passage; and a study of these rivers and their char-



	A. B.	On end Jetties
Hyd. Rad.	18.19	14.99
Area	10.189	9088
Wet P.	560	606

FIG. 10.

acteristics makes a person cautious in making up his mind. The hydraulic depth, mean radius, area, and wetted perimeter can be procured; but they will be very different in different places on the same

stream. The forms of the bottoms are peculiar, there being shoals, hollows and deposits of sand where they would not be expected. The engineer officers have, therefore, problems before them that are very difficult to solve, and more difficult also, after the course is decided as the best, is it to predict the result. The power of the Pacific waves with their long fetch is tremendous; and since the plan of appropriation is hampering, almost all projects having to lag at times on account of appropriations falling short, the works being in an unfinished state, are often injured by the storms and waves.

There are other projects in the matter of river improvement, which include blasting and removal of rock, snagging, etc. At the locks at the cascades of the Columbia some extremely fine work is being done by the Government. The officers of the Corps of Engineers on the Pacific coast are hard workers, and quite alive to the importance of the works under their direction.

The immense supply of the best timber, the late discoveries of coal and other minerals in the States of Oregon and Washington, are calling imperatively for the prosecution of these improvements with diligence and dispatch.

The author has approached this subject with diffidence and with the desire for increase of knowledge, from the discussion of the projects mentioned, by members of our society of matured knowledge and national reputation.

DISCUSSION.

George H. Mendell, M. Am. Soc. C. E.—Harbors and river mouths opening to the Pacific Ocean are entered by passing over outlying bars of sand, upon which the depth is less than it is on either side, seaward or landward. When the bar depth is small, the channel is subject to sudden changes caused by waves. The southwest storms develop waves which resolve into breakers in depths of 10 or 12 fathoms or more. Moderate gales cause disturbance of the bottom in smaller depths. Abrasion of the bed or erosion of adjoining shoals may cause sufficient movement of sand to nearly close channels, when not of considerable width and depth. Other influences produce similar effects. The summer winds blowing from the northwest transport large volumes of sand on adjacent shores. The currents—flood, ebb and littoral—are constant factors in the movement of sand to and fro. In the bights of

the coast a palpable littoral current makes to the northward during the summer months when northerly winds prevail. On some parts of the coast this movement is masked or reversed during the prevalence of storm winds from the southwest. Seaward of this littoral current, the ocean circulation due to the Japan stream, modified more or less by winds, follows the coast from north to south. Much remains to be learned of the extent and characteristics of these currents.

If we attempt to estimate the direction of the resultant littoral sand movement by the deposits shown on published charts, we shall be led to think that no general rule applies. A chart records conditions as found at a particular date. It affords no information as to either former or later conditions. The evidence of published charts needs to be supplemented by additional facts. It is maintained by some that the movement is in one direction in the summer and in the opposite direction in the winter, and in both cases obedient to the wind. This view seems probable. The evidence of the jetties constructed at the Columbia River, at Yaquina Bay and at the Coquille River, all on the south side, seems to demonstrate a sand movement of magnitude at these points to the north. At no point are north side jetties sufficiently advanced to afford evidence of the same character.

This interesting question has been studied, and it is hoped that the conditions of sand movement will soon be determined at a number of points, and the influence of the factors entering into this movement be severally ascertained.

Universality in occurrence of bars indicates that they are a necessary feature produced by the interaction of natural forces. The sand of which they are composed exists in abundance on the bed of the ocean and in adjoining shores. The bar in its position and depth represents at any period a relation of equilibrium between opposing forces—those that make to obstruct and those that make to open a passage. If the bar grows in extent or moves shoreward, or, keeping its position, lessens in depth, these are indications that the obstructing forces have gained upon their opponents. A reduction in the amount of the obstructing force, or a better application of the deepening force, brings about converse phenomena.

At the Columbia River the north head is Cape Disappointment, a basaltic cliff. The south head is Point Adams, the northern extremity of a stretch of sandy coast. It is retired to the eastward about 4 miles in rear of the Cape. From Point Adams a long and wide shoal known as Clatsop Spit makes out to the west, for more than 3 miles. This spit takes different forms in plan, and in its history has varied greatly in elevation, having been for an interval of two or three years several feet above low water. In this state it formed a natural jetty and served as far as its influence extended to concentrate the tidal ebb and flow in the main river. During other periods, its surface lay 6 to 8 or 10 feet

below the plane of low water, with one or more secondary channels through it of greater depths. In this condition the inflow and outflow were dispersed, a considerable fraction passing over or through the spit, thus reducing the amount of water circulating in the main channel. When the spit stood for 2 or 3 miles of its length above the plane of low water, the depth on the bar at low tide was 27 feet. In the other condition of the spit, the bar depth was 18 to 20 feet. These conditions of the bar and spit having been established by surveys and thus made matters of record, the proper method of bar improvement was thereby plainly suggested. If Clatsop Spit could be built up to stand several feet above the plane of low water and be maintained at this level, it was to be expected that increased depth on the bar would follow, and be maintained. Northerly movement of sand at this point is proved by the existence of the spit, and a barrier placed along the spit must arrest the sand carried by the flood tide or moved by the southerly waves. The barrier consists of a mound of riprap stone placed on mattresses of brush, all material being deposited from a timber tramway. This work is now advanced about 4 miles in incomplete condition, and stands for about 2 miles several feet above low water. Its effect has been to collect sand to the south of it, in such quantities as to create a large acreage visible at low water, in positions where the water was 6 to 10 feet deep four or five years ago; with the result of a marked increase of width and depth in the bar channel several miles seaward.

A similar construction on the south line of the entrance of Yaquina Bay has served to collect sand rising above low water to the south of the work, nearly to its extremity, and to increase the low water bar depth from 7 to 13 feet.

Fig. 9 in the paper shows the position of the jetties at Yaquina Bay. The axis of the channel prolonged passes to the southward of the outlying reef. A principle which guides in this project is to secure for the entrance, as far as practicable, protection from westerly swell, by placing it under the lee of the reef, in a position which shall permit free egress and ingress. Both jetties are yet uncompleted.

Jetties of this construction being formed of riprap stone of moderate sizes without bond, are not intended to withstand the blows of heavy waves. When placed upon a shoal where they serve to collect sand, they are protected by the deposit to windward. The waves break at a safe distance and so far from threatening the safety of the structure they give further security by increasing the mass of sand. Under such circumstances the work may be safely carried to half tide or higher. But in positions of real exposure to waves the work must be kept low, to permit the blow to pass clear; or the construction will need to be charged or strengthened by making the profile larger and by the use of heavier material. Thus far there has been no necessity of this kind.

At the Columbia River there is but a single jetty, and that is on the south side, the natural bank forming the other jetty.

While there appears to be no danger from the windward side, care must generally be taken to protect the work on the channel side. The ebb tide following the line of the work may undermine the foundation mattress which at the Columbia River is for part of the length between 12 and 18 feet below low water. The sea waves entering the channel, if permitted to race along the work, may produce the same effect, ending in the overthrow of a part of the structure and the opening of a new channel across the line. Generally there is danger to the jetty where deep water is found close along the line. A suitable alignment slightly convex to the channel affords some protection against both these dangers, which may be further obviated by a system of groins extended from the work channel-ward, which shall keep waves and currents at a safe distance and favor deposits between the groins. These jetties serve to increase the depth over the bar, but they do not efface it. It is moved out to deeper water and there is deeper water over it, but it remains. The water being deeper, the bar is less subject than before to change or deformation. The tidal currents flood and ebb having been concentrated in the same path, the ebb tide is discharged to the best advantage, and the outflow is enabled with more success to resist the efforts of the ocean waves, or other forces acting to obstruct; or, if not entirely successful for the time in preventing a certain injury, is better able, by persistent effort, to repair it after the storm has passed.

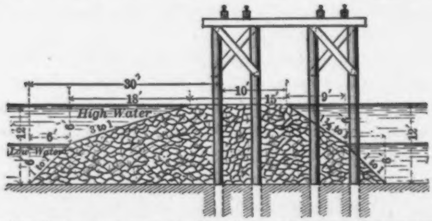
The first improvement undertaken by the Government on the Pacific Coast was that of a small lagoon on the Southern Coast of California, known as Wilmington Harbor. This improvement has proved to be notably successful. The tidal area of the lagoon is about 1 300 acres. principally made up of flats, bare at low water, and overflowed by the tide. The mean rise of tide is 4 feet, the maximum about 8 feet. The original low tide depth of water at the entrance varied from 1 to 2 feet. The existing depth of the same stage of tide is 13.5 feet. This depth is practically constant. Vessels drawing from 16 to 18 feet may now enter at high water. This improvement resulted from concentration of the tidal currents between jetties, made partly of timber and partly of stone, supplemented by a moderate amount of dredging. It is here alluded to as an illustration of the advantage of a debouche upon a coast protected from the frequent inrush of heavy sea waves. Storms on this part of the coast are rare and an outlying island in front of the harbor cuts off most part of the western swell. Upon a more exposed coast, no improvement of so small a harbor could have reached so successful a result. Harbors on more exposed parts of the coast with ten times the tidal area, and more than ten times the tidal prism, have in their present unimproved state much less water at their entrance than Wilmington has.

The works mentioned are now in course of construction, but none are completed. In every case there has been substantial improvement, but

it is yet too early to make up final judgment, which must be determined by time. A beginning has been made in the execution of a project for improving the entrance of Humboldt Bay, California, by two jetties. Plans and appropriations of money have been made also for Coos Bay, in Oregon, and San Diego, in California, but no work has been done.* Each of these three bays has a tidal area of 25 square miles or more, and a mean tidal expense of 80 000 cubic feet per second or more. Humboldt and Coos Bays debouch on a coast line exposed to heavy westerly swell and are situated in sand belts, where large quantities are in motion. Usually the prevailing low water depth on these bars is but 10 or 12 feet. In each of these cases one or both the headlands is sand. This is also true of every harbor entrance where improvement has been undertaken. This fact is mentioned as illustrating the prevalence of sand in a movable position, which in connection with the heavy waves that move it forms the great obstacle to permanent improvement.

Other bays of tidal prism sufficient to justify substantial works of improvement are Grays Harbor and Willapah or Shoalwater Bay, on the coast of Washington. The rivers of the Pacific Coast, except the Columbia, are too small to ever have considerable depths at entrance.

All jetties have perforce been built from a tramway, carrying a double car track. Mattresses of brush are built under the tracks, suspended from the caps, and when sufficiently loaded with stone are let down into place. At the Columbia River improvement a second line of mattresses



THIS CUT SHOWS LOCATION OF TRAMWAYS FOR JETTY CONSTRUCTION.

is placed on the channel side of the tramway. They are made as here, brought on cars and tilted into position. In the interval of time between driving the piles and placing the mattress, it is generally found that scouring occurs. This is an advantage in many cases, as it places the foundation of the work in a stable position, or at least in a position less exposed to undermining. The material of the jetty above the mattress is always the stone of the country, discharged from tilting cars. This is enforced by considerations of economy. The best work is done by stones of varied sizes, the smaller filling the voids of the larger, and together forming as close work as can be expected from the

* The north jetty at Coos Bay has been begun and extended in a partially completed condition for a distance of 4 500 feet.

enforced methods of construction, and sufficiently good for the purpose in view. The maximum weight at the Columbia River improvement is about 6 or 7 tons.

At the Coquille River the channel originally made to the south, following a dangerous course through the reef. The effect of the south jetty has been to make a direct course to the west free from hidden dangers. The original depth was 3 feet. It is now 6 feet. The project aims to secure 8 feet, to which the rise of the tide will add 5 or 6 feet. The position of the jetties as projected is shown in Fig. 7. They are as yet incomplete.

Wilmington is a tidal harbor, there being no fresh water drainage worth mention. San Diego is also a tidal harbor. The harbors on the northern coast are mainly tidal, although they receive during the rainy season a certain amount of drainage. Even in the Columbia, which is one of the large rivers of the Continent, navigation at its mouth is mainly dependent upon the tide in the sense that if there was no tide the entrance would not admit large vessels at all seasons. The same is true in even greater degree of San Francisco Harbor, in which backwater is quite insignificant compared with the prism made by 400 square miles of area covered by the tide twice per day.

The mean rise of the tides increases with the latitude; being about 4 feet on the southern coast of California, and about 7 feet at the Columbia River. Exposure also increases with latitude.

Restraint of sands which may be moved in considerable quantities by natural agencies to new positions within the tidal area, is a necessary feature in a project for harbor improvement. The tidal area may be lessened by encroachment, thereby producing a reduction of prism, and the swerving force may be further diminished by the duty imposed upon it of carrying foreign matter, leaving less force useful for erosion where needed. Moreover, the sand carried by the ebb may be deposited in the sea in unfavorable positions. The project for improvement of the entrance at Coos Bay, which is perhaps the most conspicuous instance we have of wind movement by sands, provides for their restraint by plantations. The sands here overwhelm houses and fences, and the tops of trees appearing through the drifts and other indications justify the inference that the accumulations are a hundred feet or more in depth. These sands reach tidal waters in very large but unknown quantities, and together with the additional amounts cut from the beach by waves or carried by currents, this element becomes a serious subject of consideration, for the reason that it is a great obstacle in the path of improvement. A beginning in planting has been made. The grass variously designated as *Arundo arenaria*, as Holland grass and as Helm, used with great success in Holland and more recently with very favorable results in San Francisco, has been set out to some extent. Other grasses, both indigenous and exotic, shrubs and pines, are undergoing

trial. There is always the question to be solved by experiment whether an exotic plant can thrive under foreign circumstances of climate and exposure. Holland grass grows well in the sands of San Francisco peninsula, and transplanted to Coos Bay a few months ago, it gives promise of life, but it is yet too early to be certain of its health and fertility.

B. W. De Courcy, M. Am. Soc. C. E.—Since writing my paper I have been engaged as Chief Engineer of the survey of Grays Harbor, for the Harbor Line Commission of the State of Washington, and the more I look at this harbor the more I am impressed that it affords the most interesting problem on the Pacific coast in Washington. On examination of the chart it will be found that the actual channel shows no soundings taken in it, the line of soundings on the north being north of the channel, that to the south being south of it, and the original chart as first drawn shows the 12-foot curve on the north side, curving and connected to the north; the south 12-foot curve being *vice versa.* When they changed it, or why, is not known, for vessels drawing as much as 17 feet have been passing out timber laden for many years, and there has never been but one accident on this bar, and that happened through mismanagement. The United States Coast and Geological Survey has made a survey which will give the correct depth in a short time.

There are no teredos to be found anywhere in the harbor. When the tide is running out the water has been found perfectly fresh, even on the bar, which is three miles outside. I think that this river, or rather so-called harbor, can be considered as an estuary, like the mouth of the Thames or Humber. Old sea captains who have been sailing in and out for over 20 years have assured me that they have never found under 19 feet on the bar, and that they have come in at all stages of the tide.

I had a tide gauge at Ocosta, and in order to ascertain how much higher the water was on the north end of the south spit, I had a line of levels carefully run from opposite to that place. I found at all times the water a foot higher there; in the center of the channel it must give a greater excess. At Aberdeen the water in the river (1 600 feet wide, 24 feet deep, at low water) is never still. The current instantly changes. I have seen logs coming in with the tide suddenly stop and immediately pass out again; and I have seen the tide running in strongly and the water falling eight-tenths on the gauge, indicating a subcurrent. The Chehalis River is deep and discharges much water. The lumber traffic is enormous, the supply inexhaustible; it must be seen to be appreciated. Some quarter sections will furnish as much as 10 000 000 feet, board measure, of merchantable lumber. The improvement of the harbor, where the railroad reaches within 5 miles of the ocean, is imperatively demanded. Ocosta has a small, though deep and well protected harbor, with a deep channel to the bar.

If my paper has done nothing else but draw out the interesting discussion by Colonel Mendell, I think it successful. Certainly Colonel Mendell knows the correct position of the reef at Yaquina, and whatever he says I should concur in. My information came from a gentleman named McMillan, a civil engineer, who was in Government employ, and I quote his words: "The reef at Yaquina lies in front of the jetties, and if they are extended too far would run up against the reef. Vessels enter the bay from the south end of the reef."

The State of Washington has made a fund for the improvement of her own harbors. The State appropriates 75 per cent. of the proceeds of the sale of the tide lands for improvement of harbors, to be laid out under the direction of the Harbor Line Commissioners. The next thing the State requires is an engineer, who should be the most skillful man to be had in all things relating to harbors.

The South Spit, at the entrance to Grays Harbor, is a black sand which contains considerable float gold. It was worked by Chinese once, but abandoned for want of fresh water to work it. They are said to have secured at the rate of $1.50 per day to the man, even with salt water.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

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Vol. XXV.—October, 1891.

SOME RECENT EXPERIMENTS WITH DYNAMITE ON AN OCEAN BAR.

By O. M. Carter, M. Am. Soc. C. E.

WITH DISCUSSION.

During the months of July and August, 1891, some experiments were made by a committee of the Board of Trade of Brunswick, Ga., with a view to temporarily increasing the depth of water over the ocean bar at the entrance to that harbor. The inner harbor, with depths in 1880 of only 9 feet at mean low water, has been improved under the direction of the United States Engineer Department until there now exists a minimum low-water channel depth of 15 feet. The outer harbor, which comprises the anchorages in Brunswick River and St. Simon's Sound, has ample depths for all classes of vessels. The entrance to the harbor is, however, obstructed by the ocean bar, which extends in a horse-shoe shape from St. Simon's Island on the north to Jekyl Island on the south. The bar has not changed much in location or in general direction within the last thirty-five years or since the date of the earliest authentic survey, but the channel across it has shoaled during that period. The mean low-water channel depth, which, in 1856, was 15 feet, was found by the survey of 1890-91 to be, in places, not more than 13.2 feet. The mean rise and fall of tide is 6.8 feet. The outer 18-foot contour had not moved appreciably seaward during

the period named, but the navigable bar channel had shifted its position toward the south, the 6-foot contour of the "north breakers" having moved southward about one-half of a mile. Some slight shoaling had also taken place in the deep pocket inside of the crest of the bar. The general outline of the locality is shown in Plate XC. The bar, which is 4 miles from land, is a narrow one, the outer and inner 15-foot mean low-water contours being separated by a distance of from 650 to 750 feet. The crest of the bar to a depth of about 20 inches, is composed of rather coarse sand and small particles of broken shells overlying sticky blue mud, which contains occasional shell fragments. The bottom in the deep pockets, both on the sea and on the harbor side of the bar, is composed of blue mud.

Some two years since, some temporary deepening of this bar was accomplished by dragging across its crest during the ebb tide a special form of scraper or harrow devised by the writer for use elsewhere on the coast, but the sand was difficult to put in suspension, and it was found impossible by that method to secure more than a few inches increase in depth.

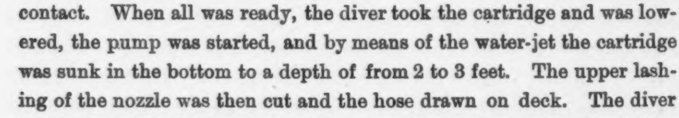
The commercial interests of the port being seriously affected by the condition of the bar, it was determined early in the present year to renew the attempt to obtain deeper water. In June, a small sum of money was appropriated by the City of Brunswick to be disbursed under the direction of a committee of the Board of Trade, and the writer was consulted as to the best method of expenditure. The methods recommended, viz.: dredging, or sluicing by propeller or water jet, could not be carried into execution on account of the impossibility of procuring a suitable plant at the proper time. The committee thereupon determined to try high explosives, notwithstanding the fact that somewhat similar work at the mouth of the Mississippi and elsewhere had proved unsuccessful. The material used comprised one tugboat, used as a tender, and for shifting anchors, etc.; one schooner, about 15 tons burden, dismantled and floored over to make a working platform; one bateau; one small skiff; one diving outfit, complete; one Gould force pump, No. 12, with 3-inch suction and 2-inch discharge, requiring four men at the brakes; six anchors; six coils of 3-inch rope; 6 000 pounds dynamite No. 2, in cartridges; one Laflin & Rand exploder, fuses, lead wires, etc.

The working party, as finally organized, consisted of one superin-

tendent, a member of the Board of Trade Committee in charge of the work, one overseer, one master of schooner, one diver, one assistant to diver, eight sailors and laborers. In addition, the crew of the tugboat rendered assistance when necessary.

The ranges for giving direction to the work having been established, the working boat was moored in position by means of bow, stern and breast lines, all of long scope, to permit of considerable freedom of movement without shifting anchors. The boat was always kept with the stem to the current. A stop was placed on the bow-line to mark the point to which the boat must return after being hauled out of the way of an explosion. The stop was moved about 15 feet each time, thus spacing the charges at that interval. From 10 to 20 pounds of dynamite were used in each charge. It was enclosed in a tin cylinder about 20 inches long and 5 inches in diameter, closed at the ends with wooden disks. The fuse wires were brought out between the wood and the tin. The cartridge was prepared by lashing it to a stick 4 or 5 feet long, to which the fuse wires were fastened to take up any accidental strain. The stick was in turn lashed to the nozzle of the hose leading from the force pump, the nozzle projecting about 2 inches below the cartridge. The whole arrangement is shown in the following sketch:

Scale: 1 inch = 1 ft.



The joints between the fuse wires and the lead wires were not insulated, but care was taken to prevent the bare portions from coming in contact. When all was ready, the diver took the cartridge and was lowered, the pump was started, and by means of the water-jet the cartridge was sunk in the bottom to a depth of from 2 to 3 feet. The upper lashing of the nozzle was then cut and the hose drawn on deck. The diver followed and the boat was hauled about 100 feet away, the lead wires being paid out. The charge was exploded and the boat brought back to its next position, 15 feet from the last. By experiment, it was found that 15-pound charges spaced 15 feet apart gave the best results. In placing a charge, the diver was under water about two minutes; the pump was worked about one minute; and the charge was exploded in

about four minutes after the diver went down. The interval between consecutive explosions was from eight to ten minutes, but as the party was not well organized and as much time was lost in going to and returning from the work, in shifting anchors, in adjusting ranges, etc., the explosion of twenty cartridges was considered a good day's work, the greatest number exploded in any one day being twenty-nine. Each discharge produced a crater about 10 feet in diameter and 5 or 6 feet deep. The material was loosened, however, a foot or more deeper, and the walls between craters were more or less broken down. The diver states that after the first few charges the bottom became so shaken and loosened, that succeeding cartridges sank into the sand more readily than did the first ones. Work was begun on the line *C D*, Plate XCI, at the inner edge of the bar, and an attempt was made to carry through a channel 50 feet in width. Considerable difficulty was experienced in keeping on range, and in the beginning the cut in places was nearly 400 feet wide. The work, however, progressed in a satisfactory manner for a distance of about 250 feet, when a compact deposit of sand and shell was encountered, through which but little progress could be made. The direction was then changed toward the north, branching off from the original cut near its inner end and crossing the outer edge of the bar about 500 feet to the northward of the original line of work. It is probable, however, that its position was not well defined or adhered to, inasmuch as few traces of it are now in existence. Operations were suspended about August 20th, after a vessel drawing 20 feet 9 inches had gone to sea through the new channel.*

In accordance with the request of the committee having charge of the work, a careful survey of the bar channels was made under the direction of the writer on September 7th, 1891. A study of this survey shows no appreciable gain in depth as a result of the work done, the mimimum low-water depth being now 13.3 feet, as against 13.2 feet before work was begun. In the old channel there is now a depth of 13.3 feet, as against 13 feet shown by the survey of 1890-91. It is probable that much more material was moved during the progress of the work than is shown by the survey, which gives only the final results obtained.

The cost of the work was about $6 000. The result was an excava-

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* The vessel went out on the high water of spring tides, and could, doubtless, have gone out through the old channel, the survey of September 7th showing the same depth in the two channels.

tion of about 6 500 cubic yards from the harbor side of the bar and a fill of about 5 000 cubic yards on its seaward side.

Referring to Plates XCI and XCII, it will be seen that a pocket 450 feet in width, 250 feet in length and with an average depth of about 1.5 feet has been cut into the inner edge of the bar, but that the crest of the bar has been moved seaward and that more or less shoaling has taken place on its outer slope. The vertical fill is, in some places, as much as 4.3 feet, and averages one foot in depth over an area of about 12 000 square feet. The width of the bar between the 15-foot mean low-water contours along the line *C D* has been reduced from 750 feet to 550 feet, and little shoaling has taken place on the seaward slope. There being along that line deep water immediately in front of the crest of the bar, it is possible that had the work been continued as originally proposed, a 15-foot channel across the bar could have been obtained.

While it is possible by the use of high explosives judiciously employed to obtain an increase of depth on ocean bars composed largely of mud or other material easily moved and of low enough specific gravity to be carried in suspension, there is nothing in the experiments recently made to indicate that the desired results can be obtained in that manner as surely or as economically as by other well known methods, especially on sites of great exposure where the work is frequently interrupted for days at a time by rough weather, and where the material composing the bar is such as to be with difficulty carried away by the tidal currents.

DISCUSSION.

CHARLES B. BRUSH, M. Am. Soc. C. E., Director Am. Soc. C. E.—Several years ago when some parties attempted to remove a gravel bar in the harbor in New York, not by explosives but by a system of water jets, the same unfortunate results were obtained. They succeeded in stirring up the material and loosening it to a considerable extent, but there was not a sufficient tide to carry the material away. It simply dropped back into its place, and after an expenditure of $6 000, it was found that the bar had not been removed to any appreciable extent.

F. COLLINGWOOD, Secretary Am. Soc. C. E.—The remark made by Mr. Brush reminds me of the visit I made in the summer to see the dredging that was going on in the lower bay here. It was very interesting, and the process has been entirely successful. It was done by a large centrifugal pump and a kind of plow attached to the suction pipes, which are some 15 inches in diameter and are flexible. The discharge

PLATE XC.
TRANS. AM. SOC. CIV. ENG'RS.
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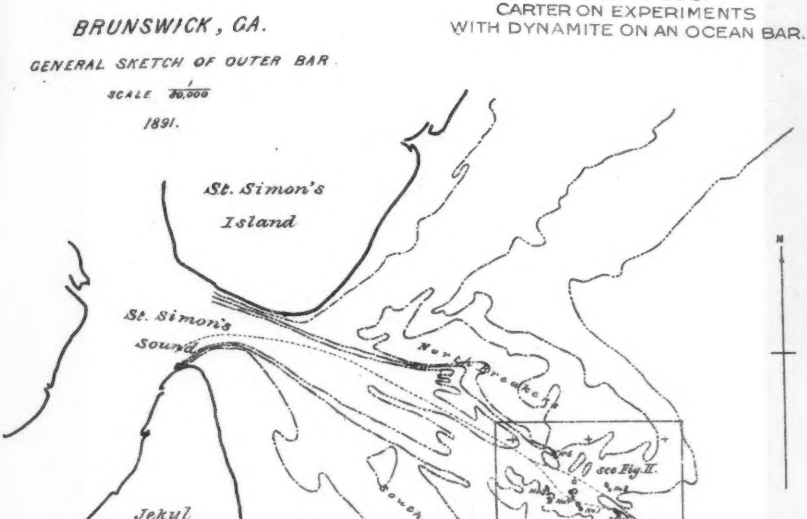
CARTER ON EXPERIMENTS
WITH DYNAMITE ON AN OCEAN BAR.



BRUNSWICK, GA.

DETAILED SKETCH OF BAR

SCALE $\frac{1}{9600}$

1891.

15 ft. m.l.w. contour before work was

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Legend

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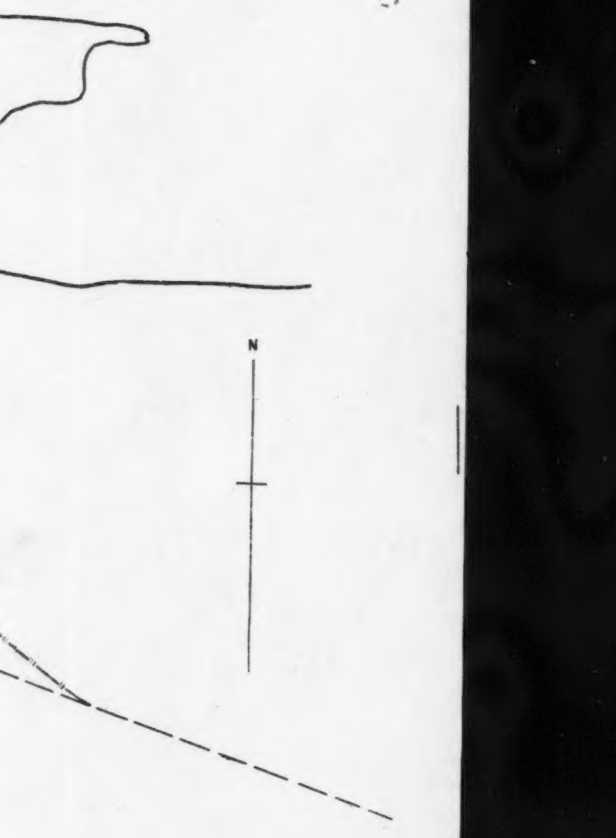
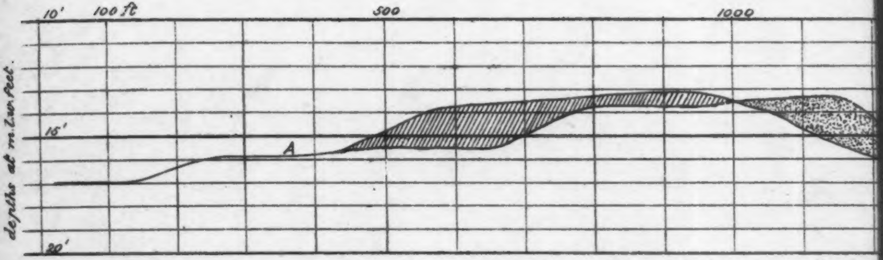
PLATE XCI.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XXV. No. 406.
CARTER ON EXPERIMENTS
WITH DYNAMITE ON AN OCEAN BAR.

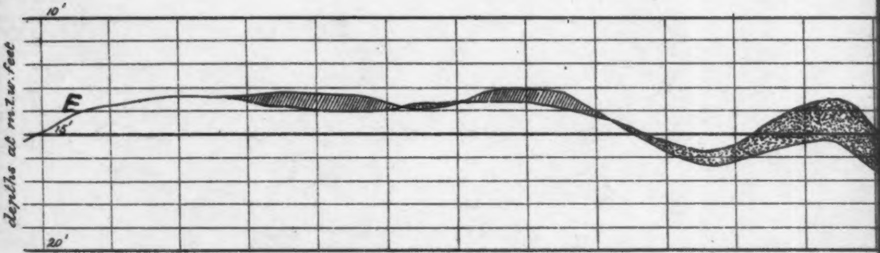


BRUNSWICK, GA

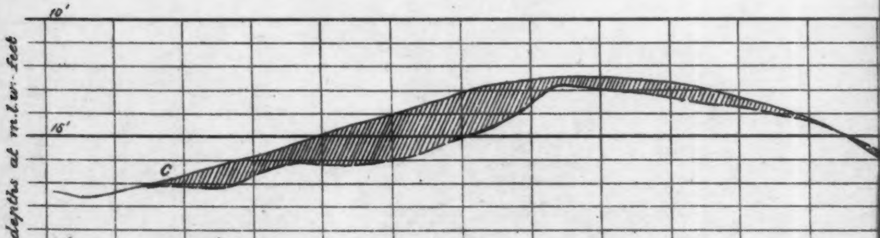
PROFILES SHOWING CHANGES



Profile on line A-B, new channe



Profile on line E-F, old channel.



Profile on line C-D, proposed

Surface of bar before work was done in fu

Cut shown thus: , Fill show

PLATE XCII.
TRANS. AM. SOC. CIV. ENG'RS.
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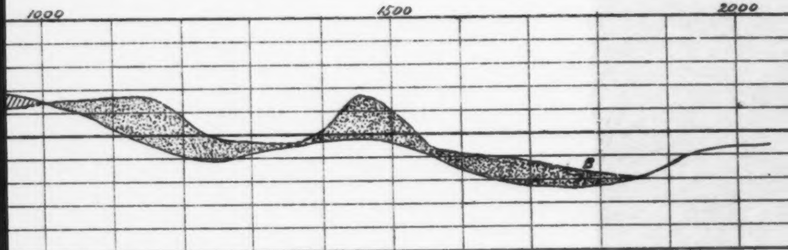
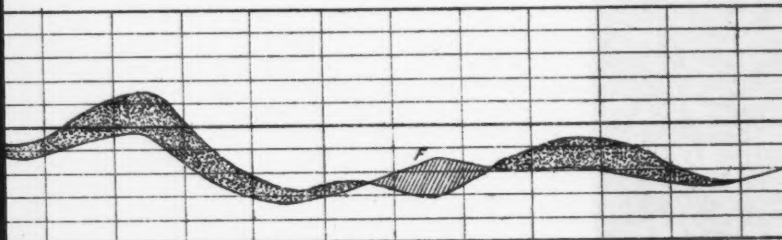
CARTER ON EXPERIMENTS
WITH DYNAMITE ON AN OCEAN BA

NSWICK, GA.

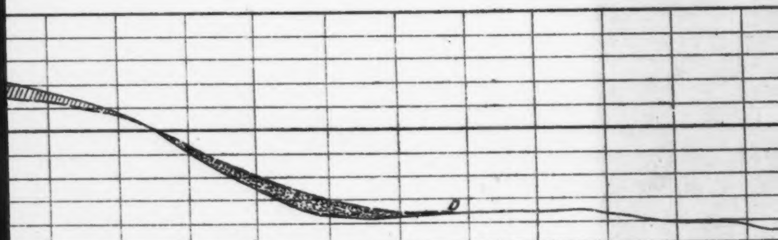
JING CHANGES IN BAR.



B, new channel.



, old channel.



-D, proposed channel.

was done in full lines, after in broken lines.

, Fill shown thus:

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is from 8 000 to 12 000 gallons a minute, and the result is that it brings up everything in the way. There is a hand hole with a cover in the top of the plow, which when opened allows the removal of any obstruction. The plow is very heavy, and it is sometimes weighted to make it take hold of the bottom; it is about 4 feet long and has partitions across it to break up any clay masses that may be met. The pumps were designed by Mr. Edwards and are some 3 feet in diameter. They have three blades only and are so arranged as to pass masses nearly a foot in diameter. At the outer end of each blade is a wrought iron plate, which if anything enters which would rupture the blade simply bends and is thrown out with the water.

The great velocity of the water brought up a heavy load of mud, sand, gravel, bricks, or anything else that the flow loosened. This was thrown into hoppers and settled to the bottom, while the water flowed off over the top. In about forty minutes 3 400 yards were lifted and deposited in the pockets of the dredge. The soundings completed over the outer channel in June show that in two years there has been very little shoaling and the channel seems to be permanent. This work was carried on always through the winter and almost without cessation.

Mr. A. Fteley, Vice-President Am. Soc. C. E., stated that in Mr. Eads' dredging at the St. Louis Bridge, a piece of cast-iron 10 inches long and 4 x 5 inches wide was sucked up and passed through one of those pumps; so they will carry up almost anything.

Mr. Brush.—The plow in the case I mention was a series of water jets that were drawn along the top of the bar, a large quantity of water being forced through these jets under very great pressure. It was hood-shaped and something in the nature of a rake, and was intended simply to stir up the material. The current was relied upon to do the rest. The quantity of material disturbed was large, but it seemed to settle down in its old place. The tide did not carry it away. In relation to this question of tides, I would like to call your attention to the fact that practically there are always three tides over that bar just as there are in the Hudson River. When the tide is flowing out on the surface another current is usually flowing in below, and still further down another is flowing out. I have frequently noticed that when material in suspension in the water is moved in one direction on the surface, it is forced back by the lower current.

J. F. Lewis, Assoc. Am. Soc. C. E.—Referring to the paper by Captain Carter, I think much better results would have been obtained by putting the charges deeper, say 6 feet or more. The same amount of powder would then have broken a crater at least 12 feet in diameter. If this could not have been done with the force pump and nozzle, it could have been accomplished with a small pile driver worked with an engine or by hand, putting down three or four holes across the line of excavation, charging each hole so soon as the bar or drill was withdrawn,

connecting the charges with wire and firing them all at the same time with an electric battery. This would have opened up a clean cut, leaving no walls between the holes, and I think the rush of water into so large an excavation would have washed out more of the material. This plan I think would have given them an excavation that could have been carried back on the proposed line without the trouble that "was experienced in keeping on the range."

Milnor P. Paret, M. Am. Soc. C. E.—There are several points brought forward in Captain Carter's interesting paper which cannot but be of general interest, and are particularly so to the writer of this article, since he was employed on the survey of 1890-91, referred to.

Captain Carter has described in detail the method of procedure, and shows us by a comparison of surveys made before and after the work was done, what the results were. However, what would appear to be the most interesting and instructive lessons to be taught by such experiments, have not been touched upon. I refer to the directions and velocities of currents at the time of the experiments, in connection with their ability to transport the material removed. That such points as these are not mentioned is due no doubt to the probability that no record of velocities, directions, etc., was kept by the parties on the work during the period of experiments.

The profiles indicate that all the work was done during the ebb tide, and, it may be supposed, on the strength of the tide (lasting three or four hours), "The time between consecutive explosions was from eight to ten minutes, and twenty explosions an average or good day's work." Twenty explosions, ten minutes apart, would occupy three and one-third hours.

Records of range of tide, times of high and low water and times of slack water, velocities and directions of currents, etc., would have been valuable in discussing a possibly proposed plan of work for permanent improvement in connection with the velocities to be generated and maintained for a permanent channel across the bar. It would seem possible that the reason so little apparent fill is shown on the seaward side of profile "C. D." is that the direction of the current might have carried the material toward "E. F.," where the fill appears excessive.

Soundings taken on an ocean bar, 4 or 5 miles from shore, and reduced to the then low water by readings on a gauge still farther from the locations of soundings and where the tidal conditions are somewhat different, can hardly be relied upon to give results within half a foot either way of the proper depth. The force and direction of the wind, the height of the sea or swell running at the time, the reliability of the leadsman and of the tests of the lead line, and the accuracy with which the soundings are plotted, are all sources of error, and even when all are reduced to their lowest limit, a margin of half a foot either way would seem to be but a small probable error. This fact would appear

to be illustrated on profile "E. F.," where at "F." there is shown a cut of 1½ feet, in 17 feet of water; this point "F." is about 650 feet from the apparent termination of the blasting on the line "E. F." It would hardly seem probable that the experimenters would move such a distance and there work in nearly 17 feet of water.

The result of the experiments has justified Captain Carter's opinion and conservativeness in not assuming the responsibility of recommending the expenditure of $6 000 on experiments promising such questionable results; but we cannot agree with him in recommending sluicing by propeller or water jet, in the face of the fact that a somewhat similar experiment made with a harrow, some two years previous, at the same point, proved that as the sand was difficult to put into suspension, only a few inches increase in depth could be obtained.

Bolton W. De Courcy, M. Am. Soc. C. E.—It appears to me that attempts to remove or improve a bar, without some plan to control the forces producing it, will only be of temporary and therefore questionable benefit; however, the immediate results seem to encourage an attempt on a larger scale, that is, a system of simultaneous blasts over the entire crest. The material composing the bar, its gravity and the velocity of the current must be carefully considered for a successful result.

Lewis McHaupt, M. Am. Soc. C. E.—In reading over the interesting description of these experiments upon the bar at Brunswick, Ga., described as having been conducted by "one superintendent, a member of the Board of Trade Committee in charge of the work," the first query suggested is, where did this civil body obtain the authority to conduct these operations in a navigable channel within the jurisdiction of the United States, and how does it happen that this report is published in advance of the annual official report of the Chief of Engineers?

It would seem from the context that the funds were provided by the City of Brunswick, "to be disbursed under the direction of a committee of the Board of Trade," and that the resident Government engineer "was consulted as to the best method of expenditure"; that he "recommended dredging or sluicing by propeller or water jet," which could not be carried into execution, and that "the committee thereupon determined to try high explosives," etc. Thus the responsibility for the method, the provision of the means for its execution and the conduct of the experiments are all ascribed to the Committee of the Board of Trade, and the function of the Government, as represented by its official, appears merely to have been to report the results unofficially through this society for the benefit of the profession.

These results might have been clearly anticipated, as the attempt to create a deeper channel on the outer bar without recourse to any modification of physical conditions which would permanently, or even temporarily, change the regimen of the currents, could not be expected to produce more than a temporary change—and as the sequel shows, the

modus operandi was defective in this, that the cut was begun on the inner slope of the bar instead of on the outer. The material loosened was therefore carried to the outer slope by the ebb and dropped in the path of the proposed extension, thus tending to increase the cost had the work been carried across the bar. It appears from the survey of September that no trace of the cut remained; the mere increase of one-tenth of a foot is altogether too small to be significant, as it is within the error of an ordinary sounding observation on soft bottom or an undulating surface, such as is almost invariably found over bars.

The fact of a vessel drawing 20 feet 9 inches having gone to sea through the new channel does not seem to have any relation to the matter; for if the original depth was 13.2 and the mean rise 6.8 feet, it would make 20 feet, while a spring tide would readily give a depth over so short a bar sufficient to float a vessel of this draught without having improved the channel. The expenditure of $6 000 to secure a net gain of about 1 000 yards with no prospect of permanent improvement is an experience which gives no promise of success, except in cases where the bottom has not been formed by gradual accretions due to natural agencies, but where rock or hard pan is found *in situ* and it is beyond the power of the current to remove it.

J. F. Le Baron, M. Am. Soc. C. E.—In the case described in the paper under discussion, it is probable that better results might have been obtained if the charges had been sunk deeper in the sand, which could have been done by using an iron pipe with the water jet pipe passed down inside. But after all we are tempted to exclaim, *Cui bono?* Supposing a continuous depth of 30 feet at low water had been obtained across the bar, how long could we expect it to keep open without protection or training walls? The result of this experiment was, that less than three weeks after the channel was obtained it was closed up completely by the shifting sands of the bar; and this is what any marine engineer would have predicted.

The outer bar of Brunswick is a part of the great littoral cordon of the Atlantic Coast. The late General Q. A. Gillmore says of it:* "This bar is caused by waves and tides and not by river sediment." In 1876 there was 17 feet on it at low water, where now there is only about 13 feet. On a bar of this kind there are always several forces unceasingly and untiringly at work to perfect and build up the littoral cordon. These are the waves and currents. The littoral cordon exists in all seas, and is particularly developed on sandy and shingly coasts. The Italians call it "the zone of sounding up."

Thomas Stevenson† says, "Wherever the heaviest waves strike obliquely on the shore, the shingle, if there be any, travels across the beach and is very apt to fill up the entrances to harbors."

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* See Report to the Chief of Engineers, United States Army (1876, I, 489).

* "Design and Construction of Harbor."

It is this same action that closed the harbor of Greytown, Nicaragua. The prevailing winds there are from the northeast, and the waves strike the beach obliquely. The beach is composed of coarse, dark colored volcanic sand, of low specific gravity, which does not compact or harden under the action of the waves, but remains soft. This sand is very easily moved, and it was carried along toward the west, in a zigzag manner, by the action of the waves, which strike the beach in the late summer and fall with great force, often sending up spray 20 feet high for days. The sand is carried alternately forward on the long hypothenuse of a right angled triangle, and then drawn down toward the sea by the reflux of the wave, to be again taken up and rolled forward on its diagonal course. In this way a tongue of sand was carried across the bay in a depth of over 40 feet of water, until it joined the western shore, and the littoral cordon was perfected, making a closed lagoon of the harbor.

Professor Henry Mitchell, Chief of Physical Hydrography on the United States Coast and Geodetic Survey, who examined this harbor in 1872 or 1873, estimated that the rate of deposit was 750 000 cubic yards per annum. He says:* "The littoral cordon is a developing physical phenomenon of the coast, distinguishing peculiarly, I think, the present geological period, and perhaps the most interesting and important among the changing features exhibited by our comparative surveys. * * * * * Upon our Southern seaboard it is the grand characteristic, and is almost continuous from Montauk to the coral reefs of Florida, and from St. Marks to Yucatan. * * * * * The tendency of the natural forces now operating upon the coast seems to be toward a complete smoothing away of all the indentures of the shore line."

As I said before, the agents that bring about this result are the waves and currents. Where there is a littoral current, this impinging against the shore tends to fill up all channels cut through the sandy cordon, and in this work the winds assist by producing or augmenting the current. On the east coast of Florida, during the winter, "northers" are of frequent occurrence. These winds are usually very strong for three days, and I have seen on the ocean beach, between Mosquito and Matanzas inlets, the well defined "rip" just outside the breakers, produced by the strong current flowing north, the wind at the same time blowing in the opposite direction, producing a banking up of the water against Cape Canaveral, and the current therefore ran against the wind to produce an equilibrium.

The waves act on the littoral cordon in two ways. Those waves that strike the bar diagonally travel along, and carry the sand with them, as I have described in the case of Greytown Harbor, filling up all indentures. Those great rollers that come in from the ocean, normal to the coast line, pile up the sand, gathered from the ocean floor, on the bar.

It is often the case that the flood tide follows a different channel from the ebb, especially on the first quarter. At Cumberland Sound, Ga.,

* Report United States Coast Survey, 1869, Reclamation of Tide Lands.

and St. John's Bar, Fla., and at numerous harbors and inlets on the New England coast, the tide first makes up inside channels along the shore, often at right angles to the ebb current. This action tends to fill up the ebb channels by deposits brought into them.

Lieutenant C. H. Davis,* U. S. Navy, shows how the flood tide takes up and ejects its burdens on the bars and beaches; but there is one phenomenon of the flood which he has not touched upon, and which I do not remember to have seen referred to by any one, and that is the difference in the character of the sand floor of the ocean or estuary during the ebb and during the flood. I first had my attention attracted to this when taking borings at Fort George Inlet, Fla., on surveys for the Florida Ship Canal. We found the sand of the beach, near low water, so hard and compact during the prevalence of the ebb tide, that with all our efforts we were unable to drive an iron rod down more than 2 feet; but after the tide turned and commenced to run up, the rod went down with little difficulty. During the ebb the sands of the beach, near low water, are also comparatively dry, and no water gathers in the foot tracks; but after the tide begins to rise, the whole bottom of the sea seems alive; the water is rising through the sand, and makes a little pool in every foot track, and the hard, compact sand floor changes to soft, yielding sand full of live water. I have noticed this fact also at the mouth of Chebacco River and Ipswich River, in Massachusetts. I took advantage of this fact in driving the iron pipes which I used for making the first ranges of the jetties which I laid out at St. John's Bar and also at Cumberland Sound. Essaying to start them before the tide turned, I found that a stalwart negro, with a heavy sledge, only succeeded in battering the top of the pipe, which could not be made to penetrate more than 2 or 3 feet; but when the tide began to rise and the sand became, as it were, alive, the pipes went down easily 6 and 8 feet. I judge from this, that the large storm rollers or ground swell, rolling in from the open sea at the first of the flood, will tear up and transport the sand from the ocean bed in shoal water, and throw it upon the littoral cordon, more readily than at any other time; and this, I think, accounts for the milky and soily character of the flood water, so often seen inside the bars.

The quotations in regard to the littoral cordon that I have given are not mere hypothesis. They are borne out amply by experience and experiment, and many more could be added. For years, however, in the face of nature and experience, efforts have been made to open and maintain cuts or channels through the littoral cordon by dredging and scraping. At St. John's Bar, Fla., $57 475.28 were expended in this desultory warfare before the construction of the jetties was commenced, and with absolutely no results, the channels formed filling up in a

* See his memoir on the "Law of Deposit of the Flood Tide," published in Smithsonian Contributions to Knowledge.

few weeks. At Nantucket Harbor, at New York Harbor, at the mouth of the Mississippi, and in fact at nearly every harbor on the Atlantic coast, this experiment has been repeatedly tried and with only one result—failure.

The Board of Trade of Brunswick might have saved their time and money; for how could they hope to succeed in the face of such a multitude of adverse facts? This method, however, might be made available and prove very advantageous for loosening and dispersing a hard sand shoal between jetties or training walls, where the current was strong enough to bear the displaced sand into deeper water; but in an unprotected cut it could be of no value, as these experiments and the experience of years have conclusively proved. It might also be used, instead of a dredge, for excavating a narrow channel or basin in the still water of an inner harbor, and much cheaper and more expeditiously; but this application would be limited to a certain depth of water, I should judge, as in comparatively shoal water the explosion could not fail to produce a crater of more or less width and depth.

Mr. Reed, M. Am. I. M. E.—Hydraulic dredges, in which the material is elevated by means of an ascending column of water, form a class distinct from that which includes bucket, dipper and clam shell dredges. The suction dredger, in which the centrifugal pump at the top of the column actuates the same, is, I believe, the only representative of the hydraulic class which has survived in practical use, though it is by no means the only style proposed or attempted. Inventors have also experimented with exhausted air chambers at the top of the tube, or with injector devices, either of water or of steam, at the foot of the tube. The sand pump used by Captain Eads in sinking the piers of the St. Louis Bridge and devised by him, employed the injector principle, an annular jet of water being used. General Roy Stone experimented in 1885, on dredging in Gedney's Channel, with an injection or induction tube having two round water jets entering the tube near its foot and directed upward. The results were unsatisfactory, though I believe some success had previously been attained with this apparatus in dredging other material than sand.

In connection with hydraulic dredges, the scraper at the base of the tube, by which the material is brought into the ascending column as the lower end of the tube is drawn along over the bottom, has been the subject of much invention and experiment. The well known boring property of a jet of water has been a favorite device for this purpose on hard bottoms. Captain Eads, in 1877, took out patents for a system of water jets attached to the scraper or plow of a suction dredger. A centrifugal pump actuated the dredging column, while force pumps actuated the stirring jets. I do not know whether this principle is utilized or not in actual practice at the present day. Suction dredgers are now used, however, extensively, notably in New York Harbor work, their great

advantage being, I believe, their capability of working at a considerable depth in a moderate seaway.

The paper just read illustrates a favorite fancy periodically revived, namely, to stir up the bottom during the ebb tide, with the expectation of the material being carried out in suspension. General Stone devised for that purpose another apparatus which he called a hydraulic plow. It consisted of a large pipe with the lower end bent upward, from which was discharged a powerful jet of water. This was dragged along the bar to be dredged, stirring up the sand and throwing it high up into the ebb current, which carried it a greater or less distance out. No practical results of value seem to have ensued, however, though the apparatus was tried quite extensively on the bar in New York Harbor in 1884.

I believe successful results were obtained some years ago on some harbor on the Pacific coast by stirring up the bottom by means of the propeller of a steamer anchored in the ebb tide, which, as it were, followed its work out as one would sweep out a room.

Having had occasion to investigate this subject some years ago, it occurred to me that the principles involved in ore dressing, with which I was familiar as a mining engineer, might be introduced to determine theoretically how far a horizontal current of water of a given velocity would transport material of a given kind in suspension before it would settle, starting from a given height. I found that the formulas worked out by Rittinger in his classic "Aufbereitungskunde," and by Von Sparre in his "Theorie der Separation," might be applied here with considerable success. The same formulas could also be used to determine the velocity of up-flow necessary in a suction dredger to carry up any given material at a given rate.

In ore dressing, the mineralized rock after being crushed consists of a great variety of particles—some of rock, some of this mineral, some of that, and ranging in size from the coarsest to fine dust or slime. The problem then is to separate out the barren rock, and to classify, if possible, the mineral particles into their various kinds; so that, for example, galena, pyrites and zinc blende will be obtained, each as far as possible free from the other. The apparatus used, such as jigs, "spitzkasten" and "spitzlutte," shaking and percussion tables, vanners, buddles, and so on, all depend upon, as fundamental principles, either the varying rate of subsidence of different kinds of particles in suspension in water, or the varying rate of rolling or sliding along a surface, of particles exposed to a horizontal current of water. It is the former of these principles which applies mainly to our case.

Rittinger's formula* for round particles settling from suspension in a horizontally moving stream of water is

$$x = \frac{y\ C}{\sqrt{d\ \frac{(\delta - \Delta)}{\Delta}\ .\ \frac{2\ \gamma}{3\ \alpha_3\ \Delta}}}$$

* All distances are to be taken in meters.

in which x = the horizontal distance to which a given particle will move before settling.

y = the depth of water through which it must settle—starting from rest.

d = the diameter of the particle.

δ = its specific gravity.

C = the horizontal velocity of the stream.

Δ = the specific gravity of the liquid, in the case of sea water say 1 026.

γ = the weight of 1 cubic meter of water in kilogrammes = 1 000.

α_3 = the pressure in kilogrammes exercised upon a sphere of one square meter principal sectional area by a column of water at a velocity of 1 meter per second. This factor is computed at 25.5.

It will be seen that both the size and the specific gravity of the particles must be taken into consideration, and that a miscellaneous assemblage of particles discharged or thrown up into a horizontally moving stream at a given height above the bottom will be deposited down stream in classified bands at right angles to the current. Any special band may contain, mingled together, certain heavy, fine particles and certain light, coarse particles. If the current be sufficiently swift to keep some particles rolling or moving after they reach the bottom, the result will be more complicated. Rittinger's formula on that subject might perhaps be applied then, were it not for the fact that the bottom will not be a plane nor a hard surface.

For irregularly shaped particles a co-efficient is introduced in the formulas which modifies the results somewhat. With ordinary sea sand the particles will be, say, quartz, the coarsest; felspar, medium; hornblende, finest. In silt will be found particles of slaty or calcareous mineral largely. I add one of Rittinger's tables and a few references on the subject of ore dressing.

Upward Velocities in meters per second of stream of fresh water necessary to hold in suspension different particles.

Material.	Specific Gravity.	Greatest Diameter of Particles in Millimeters.							
		10	8	6	4	3	2	1	½
Galena	7.5	.62	.55	.48	.39	.34	.20	.20	.14
Pyrites	5.	.49	.43	.38	.30	.26	.22	.15	.10
Quartz	2.6	.30	.27	.24	.19	.17	.14	.10	.07
Coal	1.3	.13	.12	.10	.08	.07	.06	.04	.03

See Rittinger, "Aufbereitungskunde," and latest supplement (not translated).

Von Sparre, "Theorie der Separation" (not translated).

Prof. H. S. Munroe, of Columbia College, "On the Movement of Solid Bodies in Water," *School of Mines Quarterly*, January, 1888.

Also list of works on ore dressing, by Prof. Munroe, in the same periodical, January, 1889.

Also papers of the American Institute of Mining Engineers on the works at Clansthal and Pribram, by J. C. F. Randolph, Vol. VI; Ellis Clark, Vol. IX.

Also Kunhardt's "Ore Dressing in Europe," published by Wiley.

Captain O. M. Carter, M. Am. Soc. C. E.—The writer's original paper having been misapprehended by some of the gentlemen participating in the discussion, it may be well, for their benefit, to reiterate some of the facts stated therein and to give some of the reasons which led to the presentation of the paper.

No money has ever been appropriated by Congress for the improvement of the ocean bar at Brunswick, Ga., and no work other than the execution of surveys has ever been done there by the United States or under the direction or control of any officer or agent thereof. When the bar had shoaled to such an extent as to seriously interfere with the commerce of the port, the City of Brunswick appropriated $5 000 for the purpose of temporary improvement, and the writer was consulted as to the best method of expenditure. The sum appropriated was so small that any attempt at permanent improvement was out of the question. The distance across the bar between the inner and outer 15-foot mean low water contours was only from 650 to 750 feet, and it was possible that if a channel were cut through the narrow shoal it might remain open for a few months, perhaps longer, and so afford a slight relief to commerce—at least permit some heavy laden vessels, which had been waiting for weeks for water enough to cross the bar, to go to sea.

The methods recommended by the writer were, as previously stated, dredging or sluicing. The exposure of the work would not permit the use of any but pump dredges with flexible suction pipes, and none could be hired at a reasonable rate for so small an amount of work. Propeller sluicing was recommended as an alternative method, and as a last resort, sluicing by water jet. Only water-ballast steamers are suitable for propeller sluicing on a bar with as great a tidal range as at Brunswick, and as no such steamer available for work was then in port, the committee, rather than wait for the arrival of a steamer, decided to experiment with high explosives, although it was informed that failure would probably be the result.

Shortly after the work was completed, newspapers on the Atlantic and Gulf coasts began to give glowing accounts of the success of the "new methods of harbor improvement," which, it was claimed, were much more successful and much less expensive than those approved

by the Corps of Engineers, inasmuch as by the use of high explosives, to quote the language of one newspaper: "What would cost the Government millions may be effected at an expense of a few thousand dollars." As a proof of the success of the work it was claimed that a vessel drawing 20 feet and 9 inches had gone to sea through the new channel.* The writer then made a survey of the bar, which showed, as was expected, no appreciable gain in depth as a result of the work done. Letters from a number of civil engineers asking about the "new methods of harbor improvement," led the writer to present the facts in the case to the society. No difficulty would have been experienced in excavating a channel through the bar with pump dredges, such as are used in New York Harbor and referred to by Mr. Collingwood, and that method of temporary improvement was recommended by the writer; but it was found to be impossible, with the funds available, to hire a suitable dredge at that time.

Replying to the criticism of Mr. Lewis, the writer is informed by the diver who did the work that the charges were sunk to depths varying from 1 to 5 feet, and that the best results were obtained with depths of from only 1 to 2 feet.

Mr. Paret's statement that soundings on the ocean bar 4 or 5 miles from shore can, as a rule, hardly be relied upon to give results within half a foot of the proper depth, is of course correct; but it is customary to sound to feet and tenths, and the results were given as obtained, without intending to claim for them absolute correctness. The writer agrees with Mr. Paret as to the value of the directions and velocities of the currents at the time of the experiments, but unfortunately no such record was kept. Mr. Paret is in error in stating that a somewhat similar experiment to sluicing with a propeller or water jet was made at Brunswick two years ago. A harrow was dragged across the bar, and gave, as stated by the writer, no sensible increase in depth. Sluicing has never been tried on Brunswick Bar, nor has propeller sluicing ever been tried, as far as the writer is aware, on a bar with any considerable swell; but there is no reason why it should not be conducted wherever dredging is practicable. Descriptions of the successful removal of bars on the Pacific Coast by propeller sluicing, referred to by Mr. Reed, will be found in the annual reports of the Chief of Engineers for 1882-85.

Mr. Haupt inquires how it happens "that this report is published in advance of the annual official report of the Chief of Engineers." The writer's official conduct and his relation to the Chief of Engineers are matters which cannot properly concern Mr. Haupt in the least, but

* That the taking to sea through the so-called "new channel" a vessel drawing 20 feet and 9 inches on high water of spring tides, is no proof of an increase in depth, was shown by the writer in his original paper, and Mr. Haupt's reiteration of that statement is, of course, correct.

for his information it may be stated that the official report of the Chief of Engineers deals with work carried on under the direction of the Engineer Department, and as the work in question was something with which that department had nothing whatever to do, the writer's paper could, of course, have no proper place in that report.

It is difficult to understand how Mr. Haupt ascertains that "the function of the Government, as represented by its official, appears merely to have been to report the results unofficially through this society for the benefit of the profession," when the Government had nothing whatever to do with the matter, and when it is distinctly stated in the original paper that the funds were provided by the City of Brunswick and disbursed under the direction of a committee of the Board of Trade, in accordance with its own plans.

Mr. Haupt evidently confuses the work with dredging, in which material is entirely removed, when he states that "*the modus operandi* was defective in that the cut was begun on the inner slope of the bar instead of the outer." Where the material composing a bar is simply thrown into suspension and pushed along by the tidal currents, work carried on during the ebb tides should be begun on the inner slope of the bar. To use an illustration with which Mr. Haupt may be more familiar than with harbor work, it would be better in sweeping a room to begin at the point farthest from the door through which the sweepings are to be borne, than to begin at the door and proceed in the other direction. The amount of material to be removed not being increased by that order, a little reflection will doubtless show him that it will not increase the cost of removal.

The interesting difference in the character of the sand floor of the ocean on the ebb and on the flood, referred to by Mr. LeBaron, is discussed in an official report on the survey of the bar at Brunswick, recently made under my direction by Lieutenant Thomas H. Rees, Corps of Engineers, but which has not yet been published. Mr. LeBaron is in error in stating that the method of excavation by high explosives might "be used instead of a dredge for excavating a narrow channel or basin in the still water of an inner harbor, and much more cheaply and expeditiously," inasmuch as the only case in which it could be used successfully in material of the character described, instead of a dredge, would be in running water and in a current strong enough to carry away the material thrown into suspension. Should he have intended "still water" to mean smooth water, as contradistinguished from the rough water of an ocean bar, it may be stated that at points where the water is considerably agitated and where strong currents prevail there is more probability of the material's being carried away than there is in smooth water where no such agitation takes place.